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Natural Theology;

OR

EVIDENCES

OF

THE EXISTENCE AND ATTRIBUTES

OF

THE DEITY,

COLLECTED FROM THE APPEARANCES
OF NATURE.

BY WILLIAM PALEY, D. D.
ARCHDEACON OF CARLISLE.

TRENTON, NEW-JERSEY:
PUBLISHED BY DANIEL FENTON.

1824.

PRINTED BY D. A. BORRENSTEIN, PRINCETON, N. J.

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Miss Katie L. H. Curtis

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S. Parker.

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TO THE

HONOURABLE AND RIGHT REVEREND

SHUTE BARRINGTON, LL. D.

LORD BISHOP OF DURHAM.

My Lord,

THE following work was undertaken at your Lordship's recommendation; and, amongst other motives, for the purpose of making the most acceptable return I could make for a great and important benefit conferred upon me.

It may be unnecessary, yet not perhaps, quite impertinent, to state to your Lordship and to the reader, the several inducements that have led me once more to the press. The favour of my first and ever-honoured Patron had put me in possession of so liberal a provision in the church, as abundantly to satisfy

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ter, and of its public value: my personal obligations I can never forget. Under a due sense of both these considerations, I beg leave to subscribe myself, with great respect and gratitude,

My Lord,

Your Lordship's faithful

And most devoted servant,

WILLIAM PALEY.

Bishop Wearmouth,
July, 1802.

Natural Theology;

&c. &c.

CHAPTER I.

STATE OF THE ARGUMENT.

IN crossing a heath, suppose I pitched my foot against a *stone*, and were asked how the stone came to be there, I might possibly answer, that for any thing I knew to the contrary, it had lain there forever: nor would it perhaps be very easy to show the absurdity of this answer. But suppose I had found a *watch* upon the ground, and it should be enquired how the watch happened to be in that place, I should hardly think of the answer which I had before given, that, for any thing I knew, the watch might have always been there. Yet why should not this answer serve for the watch, as well as for the stone? Why is it not as admissible in the second case as in the first? For this reason, and for no other, viz. that, when we come to inspect the watch, we perceive (what we could not discover in the stone) that its several parts are framed and put together for a purpose, e. g. that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that, if the several parts had been dif-

ferently shaped from what they are, or of a different size from what they are, or placed after any other manner or in any other order, than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use, that is now served by it. To reckon up a few of the plainest of these parts, and of their offices, all tending to one result:—We see a cylindrical box containing a coiled elastic spring, which, by its endeavour to relax itself, turns round the box. We next observe a flexible chain (artificially wrought for the sake of flexure) communicating the action of the spring from the box to the fusee. We then find a series of wheels, the teeth of which, catch in and apply to, each other, conducting the motion from the fusee to the balance, and from the balance to the pointer; and at the same time, by the size and shape of those wheels, so regulating that motion, as to terminate in causing an index, by an equable and measured progression, to pass over a given space in a given time. We take notice that the wheels are made of brass, in order to keep them from rust; the springs of steel, no other metal being so elastic; that over the face of the watch there is placed a glass, a material employed in no other part of the work; but, in the room of which, if there had been any other than a transparent substance, the hour could not be seen without opening the case. This mechanism being observed (it requires indeed an examination of the instrument, and perhaps some previous knowledge of the subject, to perceive and understand it; but being once, as we have said, observed and understood,) the inference, we think, is inevitable; that the watch must have had a maker; that there must have existed, at some time and at some place or other, an artificer or

artificers, who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use.

I. Nor would it, I apprehend, weaken the conclusion, that we had never seen a watch made; that we had never known an artist capable of making one; that we were altogether incapable of executing such a piece of workmanship ourselves, or of understanding in what manner it was performed; all this being no more than what is true of some exquisite remains of ancient art, of some lost arts, and to the generality of mankind, of the more curious productions of modern manufacture. Does one man in a million know how oval frames are turned? Ignorance of this kind exalts our opinion of the unseen and unknown artist's skill, if he be unseen and unknown, but raises no doubt in our minds of the existence and agency of such an artist, at some former time, and in some place or other. Nor can I perceive that it varies at all the inference, whether the question arise concerning a human agent, or concerning an agent of a different species, or an agent possessing, in some respects, a different nature.

II. Neither, secondly, would it invalidate our conclusion, that the watch sometimes went wrong, or that it seldom went exactly right. The purpose of the machinery, the design, and the designer, might be evident, and in the case supposed would be evident, in whatever way we accounted for the irregularity of the movement, or whether we could account for it or not. It is not necessary that a machine be perfect, in order to show with what design it was made: still less necessary, where the only question is, whether it were made with any design at all.

III. Nor, thirdly, would it bring any uncertainty into the argument, if there were a few parts of the watch, con-

cerning which we could not discover, or had not yet discovered, in what manner they conduced to the general effect; or even some parts, concerning which we could not ascertain, whether they conduced to that effect in any manner whatever. For, as to the first branch of the case; if, by the loss, or disorder, or decay of the parts in question, the movement of the watch were found in fact to be stopped, or disturbed, or retarded, no doubt would remain in our minds as to the utility or intention of the parts, although we should be unable to investigate the manner according to which, or the connexion by which, the ultimate effect depended upon their action or assistance; and the more complex is the machine, the more likely is this obscurity to arise. Then, as to the second thing supposed, namely, that there were parts, which might be spared without prejudice to the movement of the watch, and that we had proved this by experiment—these superfluous parts, even if we were completely assured that they were such, would not vacate the reasoning which we had instituted concerning other parts. The indication of contrivance remained, with respect to them, nearly as it was before.

IV. Nor, fourthly, would any man in his senses think the existence of the watch, with its various machinery, accounted for, by being told that it was one out of possible combinations of material forms; that whatever he had found in the place where he found the watch, must have contained some internal configuration or other; and that this configuration might be the structure now exhibited; viz. of the works of a watch, as well as a different structure.

V. Nor, fifthly, would it yield his inquiry more satisfaction to be answered, that there existed in things a prin-

ciple of order, which had disposed the parts of the watch into their present form and situation. He never knew a watch made by the principle of order; nor can he even form to himself an idea of what is meant by a principle of order, distinct from the intelligence of the watchmaker.

VI. Sixthly, he would be surprised to hear, that the mechanism of the watch was no proof of contrivance, only a motive to induce the mind to think so.

VII. And not less surprised to be informed, that the watch in his hand was nothing more than the result of the laws of *metallic* nature. It is a perversion of language to assign any law, as the efficient, operative cause of any thing. A law presupposes an agent; for it is only the mode, according to which an agent proceeds: it implies a power; for it is the order, according to which that power acts. Without this agent, without this power, which are both distinct from itself, the *law* does nothing; is nothing. The expression, "the law of metallic nature," may sound strange and harsh to a philosophic ear, but it seems quite as justifiable as some others which are more familiar to him; such as "the law of vegetable nature"—"the law of animal nature," or indeed as "the law of nature" in general, when assigned as the cause of phenomena, in exclusion of agency and power; or when it is substituted into the place of these.

VIII. Neither, lastly, would our observer be driven out of his conclusion, or from his confidence in its truth, by being told that he knew nothing at all about the matter. He knows enough for his argument. He knows the utility of the end: he knows the subserviency and adaption of the means to the end. These points being known, his

ignorance of other points, his doubts concerning other points, affect not the certainty of his reasoning. The consciousness of knowing little, need not beget a distrust of that which he does know.

CHAPTER II.

STATE OF THE ARGUMENT CONTINUED.

SUPPOSE, in the next place, that the person who found the watch, should, after some time discover, that in addition to all the properties which he had hitherto observed in it, it posessed the unexpected property of producing in the course of its movement, anothor watch like itself (the thing is conceivable;) that it coutained within it a mechanism, a system of parts, a mould for instance, or a complex adjustment of laths, files, and other tools, evidently and seperately calculated for this purpose; let us inquire, what effect ought such a discovery to have upon his former conclusion.

I. The first effect would be to increase admiration of the contrivance, and his conviction of the consummate skill of the contriver. Whether he had regarded the object of the contrivance, the distinct apparatus, the intricate, yet in many parts intelligible, mechanism by which it was carried on, he would perceive, in this new observation, nothing but an additional reason for doing what he had already done; for referring the construction of the watch to design, and to supreme art. If that construction *without* this property, or, which is the same thing, before this property had been noticed, proved intention and art to have been imployed about it; still more strong would the proof appear, when he came to the knowledge of this further property, the crown and perfection of all the rest.

II. He would reflect, that though the watch before him were, *in some sense*, the maker of the watch, which was fabricated in the course of its movements, yet it was in a very different sense from that, in which a carpenter, for instance, is the maker of a chair; the author of its contrivance, the cause of the relation of its parts to their use. With respect to these, the first watch was no cause at all to the second: in no such sense as this, was it the author of the constitution and order, either of the parts which the new watch contained, or of the parts by the aid and instrumentality of which it was produced. We might possibly say, but with great latitude of expression, that a stream of water ground corn: but no latitude of expression would allow us to say, no stretch of conjecture could lead us to think, that the stream of water built the mill, though it were too ancient for us to know who the builder was. What the stream of water does in the affair is neither more nor less than this; by the application of an intelligent impulse to a mechanism previously arranged, arranged independently of it, and arranged by iutelligence, an effect is produced: viz. the corn is ground. But the effect results from the arrangement. The force of the stream cannot be said to be the cause or author of the effect, still less of the arrangement. Understanding and plan in the formation of the mill were not the less necessary, for any share which the water has in grinding the corn; yet is this share the same, as that which the watch would have contributed to the production of the new watch, upon the supposition assumed in the last section. Therefore,

III. Though it be now no longer probable, that

the individual watch which our observer had found was made immediately by the hand of an artificer, yet doeth not this alteration in any wise effect the inference, that an artificer had been originally employed and concerned in the production. The argument from design remains as it was. Marks of design and contrivance are no more accounted for now, than they were before. In the same thing, we may ask for the cause of different properties. We may ask for the cause of the colour of a body, of its hardness, of its heat; and these causes may be all different. We are now asking for the cause of that subserviency to an use, that relation to an end, which we have remarked in the watch before us. No answer is given to this question by telling us that a preceding watch produced it. There cannot be design without a designer; contrivance without a contriver; order without choice; arrangement, without any thing capable of arranging; subserviency and relation to a purpose, without that which could intend a purpose; means suitable to an end, and, executing their office in accomplishing that end, without the end ever having been contemplated, or the means accomodated to it. Arrangement, disposition of parts, subserviency of means to an end, relation of instruments to an use, imply the presence of intelligence and mind. No one, therefore can rationally believe, that the insensible, inanimate watch, from which the watch before us issued, was the proper cause of the mechanism we so much admire in it; could be truly said to have constructed the instrument, disposed its parts, assigned their office, determined their order, action, and mutual dependency, combined their several motions into one result, and that also a result, connected

with the utilities of other beings. All these properties therefore, are as much unaccounted for, as they were before.

IV. Nor is any thing gained by running the difficulty farther back, i. e. by supposing the watch before us to have been produced from another watch, that from a former, and so on indefinitely. Our going back ever so far brings us no nearer to the least degree of satisfaction upon the subject. Contrivance is still unaccounted for. We still want a contriver. A designing mind is neither supplied by this supposition, nor dispensed with. If the difficulty were diminished the further we went back, by going back indefinitely we might exhaust it. And this is the only case to which this sort of reasoning applies. Where there is a tendency, or, as we increase the number of terms, a continual approach towards a limit, *there*, by supposing the number of terms to be what is called infinite, we may conceive the limit to be attained: but where there is no such tendency or approach, nothing is effected by lengthening the series. There is no difference as to the point in question, (whatever there may be as to many points) between one series and another; between a series which is finite and a series which is infinite. A chain, composed of an infinite number of links, can no more support itself, than a chain composed of a finite number of links. And of this we are assured, (though we never *can* have tried the experiment) because, by increasing the number of links, from ten, for instance, to a hundred, from a hundred to a thousand, &c. we make not the smallest approach, we observe not the smallest tendency, towards self-surport. There is no difference in this respect (yet there may be a great difference in several respects) between a

chain of a greater or less length, between one chain and another, between one that is finite and one that is indefinite. This very much resembles the case that is before us. The machine, which we are inspecting, demonstrates, by its construction, contrivance and design. Contrivance must have had a contriver; design, a designer; whether the machine immediately proceeded from another machine or not. That circnmstance alters not the case. That other machine may, in like manner, have proceeded from a former machiue: nor does that alter the case: contrivance must have had a contriver. That former one from one preceeding it: no alteration still: a contriver is still necessary. No tendency is perceived, no approach towards a diminution of this necessity. It is the same with any and every succession of these machines; a succession of ten, of a hundred, of a thousand; with one series as with another; a series which is finite, as with a series which is infinite. In whatever other respects they may differ, in this they do not. In all equally, contrivance and design are unaccounted for.

The question is not simply, How came the first watch into existence? which question, it may be pretended, is done away by supposing the series of watches thus produced from one another to have been infinite, and consequently to have had no such *first*, for which it was necessary to provide a cause. This perhaps, would have been nearly the state of the question if nothing had been before us but an unorganized, unmechanized substance, without mark or indication of contrivance. It might be difficult to show that such substance could not have existed from eternity, either in succession (if it were possible, which I think is not, for unorganized bodies to spring from one another,) or by individual

perpetuity. But that is not the question now. To suppose it to be so, is to suppose that it made no difference whether we had found a watch or a stone. As it is, the metaphysics of that question have no place; for, in the watch which we are examining, are seen contrivance, design; an end, a purpose; means for the end, adaptation to the purpose. And the question, which irresistibly presses upon our thoughts, is, whence this contrivance and design? The thing required is the intending mind, the adapting hand, the intelligence by which that hand was directed. This question, this demand, is not shaken off, by increasing a number of succession of substances, destitute of these properties; nor the more, by increasing that number to infinity. If it be said, that, upon the supposition of one watch being produced from another in the course of that other's movements, and by means of the mechanism within it, we have a cause for the watch in my hand, viz. the watch from which it proceeded, I deny, that for the design, the contrivance, the suitableness of means to an end, the adaptation of instruments to an use (all which we discover in a watch,) we have any cause whatever. It is in vain, therefore, to assign a series of such causes, or to allege that a series may be carried back to infinity; for I do not admit that we have yet any cause at all for the phenomena, still less any series of causes either finite or infinite. Here is contrivance, but no contriver: proofs of design, but no designer.

V. Our observer would further also reflect, that the maker of the watch before him, was, in truth and reality the maker of every watch produced from it; there being no difference (except that the latter manifests a more exquisite skill) between the making of another watch

with his own hands by the mediation of files, lathes, chisels, &c. and the disposing, fixing, and inserting, of these instruments, or of others equivalent to them, in the body of the watch already made, in such a manner as to form a new watch in the course of the movements which he had given to the old one. It is only working by one set of tools, instead of another.

The conclusion which the *first* examination of the watch, of its works, construction, and movement suggested, was, that it must have had, for the cause and author of that construction, an artificer, who understood its mechanism, and designed its use. This conclusion is invincible. A *second* examination presents us with a new discovery. The watch is found, in the course of its movement, to produce another watch, similar to itself: and not only so, but we perceive in it a system of organization, seperately calculated for that purpose. What effect would this discovery have or ought it to have, upon our former inference? What, as hath already been said, but to increase, beyond measure, our admiration of the skill, which had been employed in the formation of such a machine? Or shall it, instead of this, all at once turn us round to an opposite conclusion, viz. that no art or skill whatever has been concerned in the business, although all other evidences of art and skill remain as they were, and this last and supreme piece of art be now added to the rest? Can this be maintained without absurdity? Yet this is atheism.

CHAPTER III.

APPLICATION OF THE ARGUMENT.

THIS is atheism: for every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of nature; with the difference, on the side of nature, of being greater and more, and that in a degree which exceeds all computation. I mean that the contrivances of nature surpass the contrivances of art, in the complexity, subtlety, and curiosity of the mechanism; and still more, if possible, do they go beyond them in number and variety: yet, in a multitude of cases, are not less evidently mechanical, not less evidently contrivances, not less evidently accommodated to their end, or suited to their office, than are the most perfect productions of human ingenuity.

I know no better method of introducing so large a subject, than that of comparing a single thing with a single thing; an eye, for example, with a telescope. As far as the examination of the instrument goes, there is precisely the same proof that the eye was made for vision, as there is that the telescope was made for assisting it. They are made upon the same principle; both being adjusted to the laws by which the transmission and refraction of rays of light are regulated. I speak not of the origin of the laws themselves; but, such laws being fixed, the construction, in both cases, is adapted to them. For instance; these laws require, in order to produce the same effect, that the rays of light, in passing from water into the eye, should

be refracted by a more convex surface, than when it passes out of air into the eye. Accordingly we find, that the eye of a fish, in that part of it called the crystalline lens, is much rounder than the eye of terrestrial animals. What plainer manifestation of design can there be than this difference? What could a mathematical instrument-maker have done more, to show his knowledge of his principle, his application of that knowledge, his suiting of his means to his end; I will not say to display the compass or excellency of his skill and art, for in these all comparison is indecorous, but to testify counsel, choice, consideration, purpose?

To some it may appear a difference, sufficient to destroy all similitude between the eye and the telescope, that the one is a perceiving organ, the other an unperceiving instrument. The fact is, that they are both instruments. And, as to the mechanism, at least as to mechanism being employed, and even as to the kind of it, this circumstance varies not the analogy at all. For observe, what the constitution of the eye is. It is necessary, in order to produce distinct vision, that an image or picture of the object be formed at the bottom of the eye. Whence this necessity arises, or how the picture is connected with the sensation, or contributes to it, it may be difficult, nay we will confess, if you please, impossible for us to search out. But the present question is not concerned in the inquiry. It may be true, that, in this, and in other instances, we trace mechanical contrivance to a certain way; and that then we come to something which is not mechanical, or which is inscrutable. But this affects not the certainty of our investigation, as far as we have gone. The difference between an animal and an automatic statue, consists in this—that, in the animal, we

trace the mechanism to a certain point, and then we are stopped, either the mechanism becoming too subtile for our discernment, or something else beside the known laws of mechanism taking place; whereas, in the automaton, for the comparatively few motions of which it is capable, we trace the mechanism throughout. But, up to the limit, the reasoning is as clear and certain in the one case as the other. In the example before us, it is a matter of certainty, because it is a matter which experience and observation demonstrate, that the formation of an image at the bottom of the eye is necessary to perfect vision. The image itself can be shown. Whatever affects the distinctness of the image, affects the distinctness of the vision. The formation then of such an image being necessary (no matter how,) to the sense of sight, and to the exercise of that sense, the apparatus by which it is formed is constructed and put together, not only with infinitely more art, but upon the self same principles of art, as in the telescope or the camera obscura. The perception arising from the image may be laid out of the question: for the production of the image, these are instruments of the same kind. The end is the same; the means are the same. The purpose in both is alike; the contrivance for accomplishing that purpose is in both alike. The lenses of the telescope, and the humours of the eye bear a complete resemblance to one another, in their figure, their position, and in their power over the rays of light, viz. in bringing each pencil to a point at the right distance from the lens; namely, in the eye, at the exact place where the membrane is spread to receive it. How is it possible, under circumstances of such close affinity, and under the operation of equal evidence, to ex-

clude contrivance from the one, yet to acknowledge the proof of contrivance having been employed, as the plainest and clearest of all propositions in the other?

The resemblance between the two cases is still more accurate, and obtains in more points than we have yet represented, or than we are, on the first view of the subject, aware of. In dioptric telescopes there is an imperfection of this nature. Pencils of light, in passing through glass lenses, are separated into different colours, thereby tinging the object, especially the edges of it, as if it were viewed through a prism. To correct this inconvenience had been long a desideratum in the art. At last it came into the mind of a sagacious optician, to inquire how this matter was managed in the eye; in which there was exactly the same difficulty to contend with, as in the telescope. His observation taught him, that in the eye, the evil was cured by combining together lenses composed of different substances, i. e. of substances which possessed different refracting powers. Our artist borrowed from thence his hint; and produced a correction of the defect by imitating, in glasses made from different materials, the effects of the different humours through which the rays of light pass before they reach the bottom of the eye. Could this be in the eye without purpose, which suggested to the optician the only effectual means of attaining that purpose?

But further; there are other points, not so much perhaps, of strict resemblance between the two, as of superiority of the eye over the telescope; yet, of a superiority, which being founded in the laws that regulate both, may furnish topics of fair and just comparison. Two things were wanted to the eye, which were not wanted, at least in the same degree, to the

telescope; and these were, the adaptation of the organ, first, to different degrees of light; and secondly, to the vast diversity of distance at which objects are viewed by the naked eye, viz. from a few inches to as many miles. These difficulties present not themselves to the maker of the telescope. He wants all the light he can get; and he never directs his instrument to objects near at hand. In the eye, both these cases were to be provided for; and for the purpose of providing for them a subtile and appropriate mechanism is introduced.

I. In order to exclude excess of light, when it is excessive, and to render objects visible under obscurer degress of it, when no more can be had; the hole or aperture in the eye, through which the light enters, is so formed, as to contract or dilate itself for the purpose of admitting a greater or less number of rays at the same time. The chamber of the eye is a camera obscura, which, when the light is too small, can enlarge its opening; when too strong, can again contract it; and that without any other assistance than that of its own exquisite machinery. It is further also in the human subject, to be observed, that this hole in the eye, which we call the pupil, under all its different dimensions retains its exact circular shape. This is a strcuture extremely artificial. Let an artist only try to execute the same. He will find that his threads and strings must be disposed with great consideration and contrivance, to make a circle, which shall continually change its diameter, yet preserve its form. This is done in the eye by an application of fibres, i. e. of strings, similar, in their position and action, to what an artist would and must employ, if he had the same piece of workmanship to perform.

II. The second difficulty which has been stated, was the suiting of the same organ to the perception of objects that lie near at hand, within a few inches, we will suppose of the eye, and of objects which were placed at a considerable distance from it, that, for example, of as many furlongs (I speak in both cases of the distance at which distinct vision can be exercised). Now, this, according to the principles of optics, that is, according to the laws by which the transmission of light is regulated, (and these laws are fixed), could not be done, without the organ itself undergoing an alteration, and receiving an adjustment, that might correspond with the exigency of the case, that is to say, with the different inclination to one another under which the rays of light reached it. Rays issuing from points placed at a small distance from the eye, and which consequently must enter the eye in a spreading or diverging order, cannot, by the same optical instrument, in the same state, be brought to a point, i. e. be made to form an image, in the same place with rays proceeding from objects situated at a much greater distance, and which rays arrive at the eye in directions nearly, and physically speaking, parallel. It requires a rounder lens to do it. The point of concourse behind the lens must fall critically upon the retina, or the vision is confused; yet, this point, by the immutable properties of light, is carried further back, when the rays proceed from a near object, than when they are sent from one that is remote. A person, who was using an optical instrument, would manage this matter by changing, as the occasion required, his lens or his telescope; or by adjusting the distance of his glasses with his hand or his screw: but how is it to be managed in the eye? What the alteration was, or in what part of the eye it took place, or by what means

it was effected (for, if the known laws which govern the refraction of light be maintained, some alteration in the state of the organ there must be), had long formed a subject of inquiry and conjecture. The change, though sufficient for the purpose, is so minute, as to elude ordinary observation. Some very late discoveries, deduced from a laborious and most accurate inspection of the structure and operation of the organ; seem at length to have ascertained the mechanical alterations which the parts of the eye undergo. It is found, that by the action of certain muscles, called the straight muscles, and which action is the most advantageous that could be imagined for the purpose—it is found, I say, that whenever the eye is directed to a near object, three changes are produced in it at the same time, all severally contributing to the adjustment required. The cornea, or outermost coat of the eye, is rendered more round and prominent; the crystalline lens underneath is pushed forwards; and the axis of vision, as the depth of the eye is called, is elongated. These changes in the eye vary its power over the rays of light in such a manner and degree as to produce exactly the effect which is wanted, viz: the formation of an image *upon the retina*, whether the rays come to the eye in a state of divergency, which is the case when the object is near to the eye, or come parallel to one another, which is the case when the object is placed at a distance. Can any thing be more decisive of contrivance than this is? The most secret laws of optics must have been known to the author of a structure endowed with such a capacity of change. It is, as though an optician, when he had a nearer object to view, should *rectify* his instrument by putting in another glass, at the same time drawing out also his tube to a different length.

Observe a new-born child lifting up his eyelids. What

does the opening of the curtain discover? The anterior part of two pellucid globes, which, when they come to be examined, are found to be constructed upon strict optical principles; the self-same principles upon which we ourselves construct optical instruments. We find them perfect for the purpose of forming an image by refraction; composed of parts, executing different offices; one part having fulfilled its office upon the pencil of light, delivering it over to the action of another part; that to a third, and so onward: the progressive action depending for its success upon the nicest, and minutest adjustment of the parts concerned; yet, these parts so in fact adjusted, as to produce, not by a simple action or effect, but by a combination of actions and effects, the result which is ultimately wanted. And forasmuch as this organ would have to operate under different circumstances, with strong degrees of light, and with weak degrees, upon near objects, and upon remote ones, and these differences demanded, according to the laws by which the transmission of light is regulated, a corresponding diversity of structure; that the aperture, for example, through which the light passes, should be larger or less; the lenses rounder or flatter, or that their distance from the tablet, upon which the picture is delineated, should be shortened or lengthened: this, I say, being the case and the difficulty, to which the eye was to be adapted, we find its several parts capable of being occasionally changed, and a most artificial apparatus provided to produce that change. This is far beyond the common regulator of a watch, which requires the touch of a foreign hand to set it; but is not altogether unlike Harrison's contrivance for making a watch regulate tself, by inserting within it a machinery, which, by the artful use of the different expansion of metals, preserves

the equability of the motion under all the various temperature of heat and cold in which the instrument may happen to be placed. The ingenuity of this last contrivance has been justly praised. Shall, therefore, a structure which differs from it, chiefly by surpassing it, be accounted no contrivance at all? or, if it be a contrivance, that it is without a contriver?

But this, though much, is not the whole: by different species of animals, the faculty we are describing is possessed, in degrees suited to the different range of vision which their mode of life, and of procuring their food, requires. Birds, for instance, in general, procure their food by means of their beak; and their distance between the eye and the point of the beak being small, it becomes necessary that they should have the power of seeing very near objects distinctly. On the other hand, from being often elevated much above the ground, living in air, and moving through it with great velocity, they require, for their safety, as well as for assisting them in descrying their prey, a power of seeing at great distance; a power, of which, in birds of rapine, surprising examples are given. The fact accordingly is, that two peculiarities are found in the eyes of birds, both tending to facilitate the change upon which the adjustment of the eye to different distances depends. The one is a bony, yet, in most species a flexible rim or hoop, surrounding the broadest part of the eye, which, confining the action of the muscles to that part, increases the effect of their lateral pressure upon the orb, by which pressure its axis is elongated for the purpose of looking at very near objects. The other is, an additional muscle, called the marsupium, to draw, upon occasion, the crystalline lens

back, and so fit the same eye for the viewing of very distant objects. By these means the eyes of birds can pass from one extreme to another of their scale of adjustment, with more ease and readiness than the eyes of other animals.

The eyes of fishes also, compared with those of terrestrial animals, exhibit certain distinctions of structure, adapted to their state and element. We have already observed upon the figure of the crystalline compensation by its roundness, the density of the medium through which their light passes. To which we have to add, that the eyes of fish, in their natural and indolent state, appear to be adjusted to near objects, in this respect differing from the human eye, as well as those of quadrupeds and birds. The ordinary shape of the fish's eye being in a much higher degree convex than that of land animals, a corresponding difference attends its muscular conformation, viz. that it is throughout calculated for *flattening* the eye.

The iris also in the eyes of fish does not admit of contraction. This is a great difference, of which the probable reason is, that the diminished light in water is never too strong for the retina.

In the eel, which has to work its head through sand and gravel, the roughest and harshest substances, there is placed before the eye, and at some distance from it, a transparent, horny, convex case, or covering, which, without obstructing the sight, defends the organ. To such an animal, could any thing be more wanted, or more useful?

Thus, in comparing together the eyes of different kinds of animals, we see, in their resemblances and distinction, one general plan laid down, and that plan

varied with the varying exigencies to which it is to be applied.

There is one property, however, common, I believe, to all eyes, at least to all which have been examined,* namely, that the optic nerve enters the bottom of the eye, not the centre or middle, but a little on one side; not in the point where the axis of the eye meets the retina, but between that point and the nose.—The difference which this makes is, that no part of an object is unperceived by both eyes at the same time.

In considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect without wonder upon the smallness, yet correctness of the picture, the subtilty of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains are all preserved; are all discriminated in their magnitudes, positions, figures, and colours. The prospect from Hampstead-Hill is compressed into the compass of a sixpence, yet circumstantially represented. A stage coach, travelling at his ordinary speed for an half an hour, passes, in the eye, only over one twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress; for it is only by means of that perception that the motion of the coach is made sensible to the eye. If any thing can abate our admiration of the smallness of the visual tablet compared with the extent of vision, it is a reflection, which the view of nature leads us, every hour, to make, viz. that, in the hands of the Creator, great and little are nothing.

* The eye of the seel or sea-calf, I understand, is an exception.—Mem. Acad. Paris, 1701, p. 123.

Sturmius, held that the examination of the eye was a cure for atheism. Beside that conformity to optical principles which its internal constitution displays, and which alone amounts to a manifestation of intelligence having been exerted in its structure; beside this, which forms, no doubt, the leading character of the organ, there is to be seen, in every thing belonging to it and about it, an extraordinary degree of care, and anxiety for its preservation, due, if we may so speak, to its value and its tenderness. It is lodged in a strong, deep, bony socket, composed by the junction of seven different bones,* hollowed out at their edges. In some few species, as that of the coatimondi,† the orbit is not bony throughout; but whenever this is the case, the upper, which is the deficient part, is supplied by a cartilaginous ligament; a substitution which shows the same care. Within this socket it is imbedded in fat, of all animal substances the best adapted, both to its repose and motion. It is sheltered by the eyebrows, an arch of hair, which, like a thatched penthouse, prevents the sweat and moisture of the forehead from running down into it.

But it is still better protected by its *lid*. Of the superficial parts of the animal frame, I know none which, in its office and structure, is more deserving of attention than the eye-lid. It defends the eye; it wipes it; it closes it in sleep. Are there, in any work of art whatever, purposes more evident than those which this organ fulfils; or an aparatus for executing those purposes more intelligible, more appropriate, or more mechanical? If it be overlooked by the observer of nature, it can only be

* Heister, Sect. 89. † Mem. R. Ac. Paris, p. 117.

because it is obvious and familiar. This is a tendency to be guarded against. We pass by the plainest instances, whilst we are exploring those which are rare and curious; by which conduct of the understanding, we sometimes neglect the strongest observations, being taken up with others, which, though more recondite and scientific, are, as solid arguments, entitled to much less consideration.

In order to keep the eye moist and clean, which qualities are necessary to its brightness and its use, a wash is constantly supplied by a secretion for the purpose; and the superfluous brine is conveyed to the nose through a perforation in the bone as large as a goose quill. When once the fluid has entered the nose, it spreads itself upon the inside of the nostril, and is evaporated by the current of warm air, which, in the course of respiration, is continually passing over it. Can any pipe or outlet for carrying off the waste liquor from a dye-house or distillery, be more mechanical than this is? It is easily perceived that the eye must want moisture; but could the want of the eye generate the gland which produces the tear, or bore the hole by which it is discharged—a hole through a bone?

It is observable that this provision is not found in fish, the element in which they live supplying a constant lotion to the eye.

It were, however, injustice to dismiss the eye as a piece of mechanism, without noticing that most exquisite of all contrivances, the nictitating membrane, which is found in the eyes of birds and of many quadrupeds. Its use is to sweep the eye, which it does in an instant; to spread over it the lachrymal humour; to defend it also from sudden injuries; yet not totally, when drawn upon the pupil, to

shut out the light. The commodiousness with which it lies folded up in the upper corner of the eye, ready for use and action, and the quickness with which it executes its purpose, are properties known and obvious to every observer; but, what is equally admirable, though not quite so obvious, is the combination of two different kinds of substance, muscular and elastic, and of two different kinds of action, by which the motion of this membrane is performed. It is not, as in ordinary cases, by the action of two antagonist muscles, one pulling forward and the other backward, that a reciprocal change is effected; but it is thus: The membrane itself is an elastic substance, capable of being drawn out by force like a piece of elastic gum, and by its own elasticity returning, when the force is removed, to its former position. Such being its nature, in order to fit it up for its office, it is connected by a tendon or thread, with a muscle in the back part of the eye; this tendon or thread, though strong, is so fine as not to obstruct the sight, even when it passes across it; and the muscle itself being placed in the *back* part of the eye, derives from its situation the advantage, not only of being secure, but of being out of the way; which it would hardly have been in any position that could be assigned to it in the anterior part of the orb, where its function lies. When the muscle behind the eye contracts, the membrane, by means of the communicating thread, is instantly drawn over the fore-part of it. When the muscular contraction (which is a positive, and most probably, a voluntary effort,) ceases to be exerted, the elasticity alone of the membrane brings it back again to its position.* Does not this, if any thing can do it,

* Phil. Trans. 1796.

bespeak an artist, master of his work, acquainted with his materials? "Of a thousand other things," say the French Academicians, "we perceive not the contrivance, because we understand them only by the effects, of which we know not the causes; but we here treat of a machine, all theparts where of are visible; and which need only be looked upon to discover, the reason of its motion and action."*

In the configuration of the muscle, which, though placed behind the eye, draws the nictitating membrane over the eye, there is, what the authors, just now quoted, deservedly call a marvellous mechanism. I suppose this structure to be found in other animals; but in the Memoirs from which this account is taken, it is anitomically demonstrated only in the cassowary. The muscle is *passed through a loop, formed by another muscle;* and is there inflected, as it were, round a pulley. This is peculiarity; and observe the advantage of it. A single muscle with a straight tendon, which is the common muscular form, would have been sufficient, if it had had power to draw far enough. But the contraction, necessary to draw the membrane over the whole eye, required a longer muscle than could lie straight at the bottom of the eye. Therefore, in order to have a greater length in a less compass, the chord of the main muscle makes an angle. This, so far, answered the end; but, still further, it makes an angle, not round a fixed pivot, but round a loop, formed by another muscle; which second muscle, when-

* Memoirs for a Natural History of Animals by the Royal Academy of Sciences at Paris, done into English by order of the Royal Society 1701, p. 249.

ever it contracts, of course twitches the first muscle at the point of inflection, and thereby assists the action designed by both.

One question may possibly have dwelt in the reader's mind during the perusal of these observations, namely, Why should not the Deity have given to the animal the faculty of vision *at once?* Why this circuitous perception; the ministry of so many means? an element provided for the purpose; reflected from opaque substances, refracted through transparent ones; and both according to precise laws: then, a complex organ, an intricate and artificial apparatus, in order, by the operation of this element, and in conformity with the restrictions of these laws, to produce an image upon a membrane communicating with the brain? Wherefore all this? Why make the difficulty in order only to surmount it? If to perceive objects by some other mode than that of touch, or objects which lay out of the reach of that sense, were the thing proposed, could not a simple volition of the Creator have communicated the capacity? Why resort to contrivance, where power is omnipotent? Contrivance, by its very definition and nature, is the refuge of imperfection. To have recourse to expedients, implies difficulty, impediment, restraint, defect of power. This question belongs to the other senses, as well as to sight; to the general functions of animal life, as nutrition, secretion, respiration; to the economy of vegetables; and indeed to almost all the operations of nature. The question, therefore, is

of very wide extent; and, amongst other answers which may be given to it, beside reasons of which probably we are ignorant, one answer is this. It is only by the display of contrivance, that the existence, the agency, the wisdom of the Deity, *could* be testified to his rational creatures. This is the scale by which we ascend to all the knowledge of our Creator which we possess, so far as it depends upon the phenomena, or the works of nature. Take away this, and you take away from us every subject of observation, and ground of reasoning; I mean as our rational faculties are formed at present. Whatever is done, God could have done, without the intervention of instruments or means: but it is in the construction of instruments, in the choice and adaptation of means, that a creative intelligence is seen. It is this which constitutes the order and beauty of the universe. God, therefore, has been pleased to prescribe limits to his own power, and to work his ends within those limits. The general laws of matter have, perhaps, the nature of these limits; its inertia, its re-action; the laws which govern the communication of motion, the refraction and reflection of light, the constitution of fluids nonelastic and elastic, the transmission of sound through the latter; the laws of magnetism, of electricity; and probably others yet undiscovered. These are general laws; and when a particular purpose is to be effected, it is not by making a new law, nor by the suspension af the old one, nor by making them wind and bend and yield to the occasion (for nature, with great steadiness adheres to, and supports them,) but it is, as we have seen in the eye, by the interposition of an apparatus, corresponding with these laws, and suited to the exigency which results from them, that the purpose is at length attained. As we have said, therefore, God pre-

scribes limits to his power, that he may let in the exercise, and thereby exhibit demonstrations of his wisdom. For then, i. e. such laws and limitations being laid down, it is as though one Being should have fixed certain rules; and, if we may so speak, provided certain materials; and, afterwards, have committed to another Being, out of these materials, and in subordination to these rules, the task of drawing forth a creation: a supposition which evidently leaves room, and induces, indeed, a necessity for contrivance. Nay, there may be many such agents, and many ranks of these. We do not advance this as a doctrine, either of philosophy or of religion; but we say that the subject may safely be represented under this view, because the Deity, acting himself by general laws, will have the same consequences upon our reasoning, as if he had prescribed these laws to another. It has been said, that the problem of creation was, "attraction and matter being given, to make a world out of them:" and, as above explained, this statement perhaps does not convey a false idea.

We have made choice of the eye, as an instance, upon which to rest the argument of this chapter. Some single example was to be proposed; and the eye offered itself under the advantage of admitting of a strict comparison with optical instruments. The ear, it is probable, is no less artificially and mechanically adapted to its office, than the eye. But we know less about it; we do not so well understand the action, the use, or the mutual dependency of its internal parts. Its general form, however, both external and and internal, is sufficient to show that it is an instrument, adapted to the reception of sound; that is to say, already knowing that sound consists in pulses of the air; we perceive in the structure of the ear, a suitableness to recieve

impression from these species of action, and to propagate these impressions to the brain. For of what does this structure consist? An external ear (the concha,) calculated, like an ear-trumpet, to catch and collect the pulses of which we have spoken;—in large quadrupeds, turning to the sound, and possessing a configuration, as well as motion, evidently fitted for the office: of a tube which leads into the head, laying at the root of this outward ear, the folds and sinews thereof tending and conducting the air towards it: of a thin membrane, like the pelt of a drum, stretched across this passage upon a bony rim: of a chain of moveable, and infinitely curious, bones, forming a communication, and the only communication that can be observed, between the membrane last mentioned and the interior channels and recesses of the skull: of cavities, similar in shape and form to wind instruments of music, being spiral or portions of circles: of the eustachian tube, like the hole in a drum, to let the air pass freely into and out of the barrel of the ear, as the covering membrane vibrates, or as the temperature may be altered: the whole labyrinth hewn out of a rock: that is, wrought into the substance of the hardest bone of the body. This assemblage of connected parts constitutes together an apparatus, plainly enough relative to the transmission of sound, or of the impulses received from sound, and only to be lamented in not being better understood.

The communication within, formed by the small bones of the ear, is, to look upon, more like what we are accustomed to call machinery, than any thing I am acquainted with in animal bodies. It seems evidently designed to continue towards the sensorium the tremulous motions which are excited in the "membrane of the tympanum,"

or what is better known by the name of the "drum of the ear." The compages of bones consists of four, which are so disposed, and so hinge upon one another, as that, if the membrane, the drum of the ear, vibrate, all the four are put in motion together, and by the result of their action, work the base of that which is the last in the series, upon which it plays, and which aperture opens into the tortuous canals that lead to the brain. This last bone of the four is called the stapes. The office of the drum of the ear is to spread out an extended surface, capable of receiving the impressions of the sound, and of being put by them into a state of vibration. The office of the stapes is to repeat these vibrations. It is a repeating frigate, stationed more within the line. From which account of its action may be understood, how the sensation of sound will be excited, by any thing which communicates a vibratory motion to the stapes, though not, as in all ordinary cases, through the intervention of the membrana tympani. This is done by solid bodies applied to the bones of the scull, as by a metal bar held at one end between the teeth, and touching at the other end a tremulous body. It likewise appears to be done, in a considerable degree, by the air itself, even when this membrane, the drum of the ear, is greatly damaged. Either in the natural or preternatural state of the organ, the use of the chain of bones is to propagate the impulse in a direction towards the brain, and to propagate it with the advantage of a lever; which advantage consists in increasing the force and strength of the vibration, and at the same time diminishing the space through which it oscillates: both of which changes may augment or facilitate the still deeper action of the auditory nerves.

The benefits of the eustachian tube to the organ, may

be made out upon known pneumatic principles. Behind the drum of the ear is a second cavity or barrel, called the tympanum. The eustachian tube is a slender pipe, but sufficient for the passage of air, leading from this cavity into the back part of the mouth. Now it would not have done to have had a vacuum in this cavity; for, in that case, the pressure of the atmosphere from without would have burst the membrane which covered it. Nor would it have done to have filled the cavity with lymph or any other secretion; which would necessarily have obstructed, both the vibration of the membrane, and the play of the small bones. Nor, lastly, would it have done to have occupied the space with confined air, because the expansion of that air by heat, or its contraction by cold, would have distended or relaxed the covering membrane, in a degree inconsistent with the purpose which it was assigned to execute. The only remaining expedient, and that for which the eustachian tube serves, is to open to this cavity a communication with the external air. In one word; it exactly answers the purpose of the hole in a drum.

The membrana tympani itself, likewise, deserves all the examination which can be made of it. It is not found in the ears of fish; which furnishes an additional proof of what indeed is indicated by every thing about it, that it is appropriated to the action of air, or of an elastic medium. It bears an obvious resemblance to the pelt or head of a drum, from which it takes its name. It resembles also a drum head in this principal property, that its use depends upon its tension. Tension is the state essential to it. Now we know that, in a drum, the pelt is carried over a hoop, and braced, as occasion requires, by the means of strings attached to its circumference. In the membrane

of the ear, the same purpose is provided for, more simply, but not less mechanically, nor less successfully, by a different expedient, viz. by the end of a bone (the handle of the malleus) pressing upon its centre. It is only in very large animals that the texture of this membrane can be discerned. In the Philosophical Transactions for the year 1800, (vol. i.) Mr. Everard Home has given some curious observations upon the ear, and the drum of the ear, of an *elephant*. He discovered in it, what he calls a radiated muscle, that is, straight muscular fibres, passing along the membrane from the circumference to the centre; from the bony rim which surrounds it, towards the handle of the malleus to which the central part is attached. This muscle he supposes to be designed to bring the membrane into unison with different sounds: but then he also discovered, that this muscle itself cannot act, unless the membrane be drawn to a stretch, and kept in a due state of tightness, by what may be called a foreign force, viz. the action of the muscles of the malleus. Our author, supposing his explanation of the use of the parts to be just, is well founded in the reflection which he makes upon it; "that this mode of adapting the ear to different sounds, is one of the most beautiful applications of muscles in the body: *the mechanism is so simple, and the variety of effects so great.*"

In another volume of the Transaction above referred to, and of the same year, two most curious cases are related, of persons who retained the sense of hearing, not in a perfect, but in a very considerable degree, notwithstanding the almost total loss of the membrane we have been describing. In one of these cases, the use here assigned to that membrane, of modifying the impressions of sound by change of tension, was attempted

to be supplied by straining the muscles of the outward ear. "The external ear," we are told, "had acquired a distinct motion upward and backward, which was observable whenever the patient listened to any thing which he did not distinctly hear; when he was addressed in a whisper, the ear was seen immediately to move; when the tone of voice was louder, it then remained altogether motionless."

It appears probable, from both these cases, that a collateral, if not principal, use of the membrane, is to cover and protect the barrel of the ear which lies behind it. Both the patients suffered from cold; one, "a great increase of deafness from catching cold;" the other, "very considerable pain from exposure to a stream of cold air." Bad effects, therefore followed from this cavity being left open to the external air; yet, had the author of nature shut it up by any other cover, than what was capable, by its texture, of receiving vibrations from sound, and by its connection with the interior parts, of transmitting those vibrations to the brain, the use of the organ, so far as we can judge, must have been entirely obstructed.

CHAPTER IV.

OF THE SUCCESSION OF PLANTS AND ANIMALS.

THE generation of the animal no more accounts for the contrivance of the eye or ear, than, upon the supposition stated in a preceding chapter, the production of a watch by the motion and mechanism of a former watch, would account for the skill and intention evidenced in the watch so produced; than it would account for the disposition of the wheels, the catching of their teeth, the relation of the several parts of the works to one another and to their common end, for the suitableness of their forms and places to their offices, for their connection, their operation, and the useful result of that operation. I do insist most strenuously upon the correctness of this comparison; that it holds as to every mode of specific propagation; and that whatever was true of the watch, under the hypothesis above mentioned, is true of plants and animals.

I. To begin with the fructification of plants. Can it be doubted but that the seed contains a particular organization? Whether a latent plantule with the means of temporary nutrition, or whatever else it be, it encloses an organization suited to the germination of a new plant. Has the plant which produced the seed any thing more to do with that organization, than the watch would have had to do with the structure of the watch which was produced in the course of its mechanical movement? I mean, Has it any thing at all to do with the *contrivance*? The maker

and contriver of one watch, when he inserted within it a mechanism suited to the production of another watch, was, in truth, the maker and contriver of that other watch. All the properties of the new watch were to be referred to his agency: the design manifested in it, to his intention: the art, to him as the artist; the collocation of each part, to his placing: the action, effect, and use, to his counsel, intelligence, and workmanship. In producing it by the intervention of a former watch, he was only working by one set of tools instead of another. So it is with the plant, and the seed produced by it. Can any distinction be assigned between the two cases: between the producing watch, and the producing plant? both passive unconscious substances; both, by the organization which was given to them, producing their like, without understanding or design; both, that is, instruments.

II. From plants we may proceed to oviparous animals; from seeds to eggs. Now I say, that the bird has the same concern in the formation of the egg which she lays, as the plant has in that of the seed which it drops; and no other, nor greater. The internal constitution of the egg is as much a secret to the hen, as if the hen were inanimate. Her will cannot alter it, or change a single feather of the chick. She can neither foresee nor determine of which sex her brood shall be, or how many of either: yet the thing produced shall be, from the first, very different in its make, according to the sex which it bears. So far, therefore, from adapting the means, she is not beforehand apprized of the effect. If there can be concealed within that smooth shell, a provision and a preparation for the production and nourishment of a new animal, they are not of her providing or preparing: if there be contrivance, it is none

of hers. Although, therefore, there be the difference of life, and preceptivity between the animal and the plant, it is a difference which enters not into the account. It is a foreign circumstance. It is a difference of properties not employed. The animal function, and the vegetable function, are alike destitute of any design which can operate upon the form of the thing produced. The plant has no design in producing the seed; no comprehension of the nature or use of what it produces: the bird, with respect to its egg, is not above the plant, with respect to its seed. Neither the one nor the other bears that sort of relation to what proceeds from them, which a joiner does to the chair which he makes. Now a cause, which bears this relation to the effect, is what we want, in order to account for the suitableness of means to an end, the fitness and fitting of one thing to another: and this cause the parent plant or animal does not supply.

It is further observable concerning the propagation of plants and animals, that the apparatus employed exhibits no resemblance to the thing produced; in this respect holding analogy with instruments and tools of art. The filaments, antheræ, and stigmata of flowers, bear no more resemblance to the young plant, or even to the seed, which is formed by their intervention, than a chisel or a plane does to a table or a chair. What then are the filaments, antheræ, and stigmata of plants, but instruments, strictly so called?

III. We may advance from animals which bring forth eggs, to animals which bring forth their young alive; and, of this latter class, from the lowest to the highest; from irrational to rational life, from brutes to the human species; without perceiving, as we proceed, any alteration

whatever in the terms of the comparison. The rational animal does not produce its offspring with more certainty or success than the irrational animal; a man than a quadruped, a quadruped than a bird; nor (for we may follow the gradation through its whole scale) a bird than a plant; nor a plant than a watch, a piece of dead mechanism, would do, upon the supposition which has already so often been repeated. Rationality, therefore, has nothing to do in the business. If an account must be given of the contrivance which we observe; if it be demanded, whence arose, either the contrivance by which the young animal is produced, or the contrivance manifested in the young animal itself; it is not from the reason of the parent that any such account can be drawn. He is the cause of his offspring, in the same sense as that in which a gardener is the cause of the tulip which grows upon his parterre, and in no other. We admire the flower; we examine the plant; we perceive the conduciveness of many of its parts to their end and office; we observe a provision for its nourishment, growth, protection, and fecundity; but we never think of the gardener in all this. We attribute nothing of this to his agency; yet it may still be true, that, without the gardener, we should not have had the tulip. Just so it is with the succession of animals, even of the highest order. For the contrivance discovered in the structure of the thing produced, we want a contriver. The parent is not that contriver. His consciousness decides that question. He is in total ignorance why that, which is produced, took its present form rather than any other. It is for him only to be astonished by the effect. We can no more look, therefore, to the intelligence of the parent animal for what we are in search of, a cause of relation and of subserviency of parts to their use, which re-

lation and subserviency we see in the procreated body, than we can refer the internal conformation of an acorn to the intelligence of the oak from which it dropped, or the structure of the watch to the intelligence of the watch which produced it; there being no difference, as far as argument is concerned, between an intelligence which is not exerted, and an intelligence which does not exist.

CHAPTER V.

APPLICATION OF THE ARGUMENT CONTINUED.

EVERY observation which was made, in our first chapter concerning the watch, may be repeated with strict propriety concerning the eye; concerning animals; concerning plants; concerning, indeed, all the organized parts of the works of nature. As,

I. When we are inquiring simply after the *existence* of an intelligent Creator, imperfection, inaccuracy, liability to disorder, occasional irregularities, may subsist, in a considerable degree, without inducing any doubt into the question: just as a watch may frequently go wrong, seldom perhaps exactly right, may be faulty in some parts, defective in some, without the smallest ground of suspicion from thence arising, that it was not a watch; not made, or not made for the purpose ascribed to it. When faults are pointed out, and when a question is started concerning the skill of the artist, or the dexterity with which the work is executed, then indeed, in order to defend these qualities from accusation, we must be able, either to expose some intractableness and imperfection in the materials, or point out some invincible difficulty in the execution, into which imperfection and difficulty, the matter of complaint may be resolved; or, if we cannot do this, we must adduce such specimens of consumate art and contrivance, proceeding from the same hand, as may convince the inquirer, of the existence, in the case before

him, of impediments like those which we have mentioned, although, what from the nature of the case is very likely to happen, they be unknown and unperceived by him. This we must do in order to vindicate the artist's skill, or, at least, the perfection of it; as we must also judge of his intention, and of the provisions employed in fulfilling that intention, not from an instance in which they fail, but from the great plurality of instances in which they succeed. But, after all, these are different questions from the question of the artist's existence; or, which is the same, whether the thing before us be a work of art or not: and the questions ought always to be kept separate in the mind. So likewise it is in the works of nature. Irregularities and imperfections are of little or no weight in the consideration, when that consideration relates simply to the existence of a Creator. When the argument respects his attributes, they are of weight; but are then to be taken in coujunction (the attention is not to rest upon them, but they are to be taken in conjunction) with the unexceptionable evidences which we possess, of skill, power, and benevolence, displayed in other instances; which evidences may, in strength, number, and variety, be such; and may so overpower apparent blemishes, as to induce us, upon the most reasonable ground, to believe, that these last ought to be referred to some cause, though we be ignorant of it, other than defect of knowledge or of benevolence in the author.

II. There may be also parts of plants and animals, as there were supposed to be of the watch of which, in some instances, the operation, in others, the use is unknown. These form different cases; for the operation may be unknown, yet the use be certain. Thus it is

with the lungs of animals. It does not, I think, appear, that we are acquainted with the action of the air upon the blood, or in what manner that action is communicated by the lungs; yet we find that a very short suspension of their office destroys the life of the animal. In this case, therefore, we may be said to know the use, nay we experience the necessity, of the organ, though we be ignorant of its operation. Nearly the same thing may be observed of what is called the lymphatic system. We suffer grievous inconveniences from its disorder, without being informed of the office which it sustains in the economy of our bodies. There may possibly also be some few examples of the second class, in which, not only the operation is unknown, but in which experiments may seem to prove that the part is not necessary; or may leave a doubt, how far it is even useful to the plant or animal in which it is found. This is said to be the case with the spleen; which has been extracted from dogs, without any sensible injury to their vital functions. Instances of the former kind, namely in which we cannot explain the operation, may be numerous; for they will be so in proportion to our ignorance. They will be more or fewer to different persons, and in different stages of science. Every improvement of knowledge diminishes their number. There is hardly, perhaps, a year passes, that does not, in the works of nature, bring some operation, or some mode of operation, to light, which was before undiscovered, probably unsuspected. Instances of the second kind, namely, where the part appears to be totally useless, I believe to be extremely rare: compared with the number of those, of which the use is evident, they are beneath any assignable proportion; and perhaps, have never been submitted to a trial and exami-

nation, sufficiently accurate, long enough continued, or often enough repeated. No accounts, which I have seen, are satisfactory. The mutilated animal may live and grow fat, as was the case of the dog deprived of its spleen, yet may be defective in some other of its functions; which, whether they can all, or in what degree of vigour and perfection, be performed, or how long preserved, without the extirpated organ, does not seem to be ascertained by experiment. But to this case, even were it fully made out, may be applied the consideration which we suggested concerning the watch, viz. that these superfluous parts do not negative the reasoning which we instituted concerning those parts which are useful, and of which we know the use. The indication of contrivance, with respect to them, remains as it was before.

III. One atheistic way of replying to our observations upon the works of nature, and to the proofs of a Deity which we think that we perceive in them, is to tell us, that all which we see must necessarily have had some form, and that it might as well be its present form, as any other. Let us now apply this answer to the eye, as we did before to the watch. Something or other must have occupied that place in the animal's head; must have filled up, we will say, that socket: we will say also, that it must have been of that sort of substance which we call animal substance; as flesh, bone, membrane, cartilage, &c.; but that it should have been an *eye*, knowing as we do what an eye comprehends, viz. that it should have consisted, first, of a series of transparent lenses (very different, by the bye, even in their substance, from opaque materials of which the rest of the body is, in general at least, composed; and with which the whole of its surface, this single portion of it ex-

cepted, is covered:) secondly, of a black cloth or canvass (the only membrane of the body which is black) spread out behind these lenses, so as to receive the image, formed by pencils of light, transmitted through them; and placed at the precise geometrical distance at which, and at which alone, a distinct image could be formed, namely, at the concourse of the refracted rays: thirdly, of a large nerve, communicating between this membrane and the brain; without which the action of light upon the membrane, however modified by the organ, would be lost to the purposes of sensation. That this fortunate conformation of parts should have been the lot, not of one individual out of many thousand individuals, like the great prize in a lottery, or like some singularity in nature, but the happy chance of a whole species; nor of one species out of many thousand species, with which we are acquainted, but of by far the greatest number of all that exist; and that under varieties, not casual or capricious, but bearing marks of being suited to their respective exigencies: that all this should have taken place, merely because something must have occupied those points in every animal's forehead; or, that all this should be thought to be accounted for, by the short answer "that whatever was there must have had some form or other," is too absurd to be made more so by any argumentation. We are not contented with this answer, we find no satisfaction in it, by way of accounting for appearances of organization far short of those of the eye, such as we observe in fossil shells, petrified bones, or other substances which bear the vestiges of animal or vegetable recrements, but which, either in respect of utility, or of the situation in which they are discovered, may seem accidental enough. It is no way of accounting even for these things, to say that the stone, for instance, which is

shown to us, (supposing the question to be concerning a petrification,) must have contained some internal conformation or other. Nor does it mend the answer to add, with respect to the singularity of the conformation, that, after the event, it is no longer to be computed what the chances were against it. This is always to be computed, when the question is, whether an useful or imitative conformation be the produce of chance or not. I desire no greater certainty in reasoning, than that by which chance is excluded from the present disposition of the natural world. Universal experience is against it. What does chance ever do for us? In the human body, for instance, chance, i. e. the operation of causes without design, may produce a wen, a wart, a mole, a pimple, but never an eye. Amongst inanimate substances, a clod, a pebble, a liquid drop, might be; but never was a watch, a telescope, an organized body of any kind, answering a valuable purpose by a complicated mechanism, the effect of chance. In no assignable instance hath such a thing existed without intention somewhere.

IV. There is another answer which has the same effect as the resolving of things into chance; which answer would persuade us to believe, that the eye, the animal to which it belongs, every other animal, every plant, indeed every organized body which we see, are only so many out of the possible varieties and combinations of being, which the lapse of infinite ages has brought into existence; that the present world is the relict of that variety; millions of other bodily forms and other species having perished, being by the defect of their constitution incapable of preservation, or of continuance by generation. Now there is no foundation whatever for this conjecture in any thing which we observe in the works of na-

ture: no such experiments are going on at present; no such energy operates as that which is here supposed, and which should be constantly pushing into existence new varieties of beings: nor are there any appearances to support an opinion, that every possible combination of vegetable or animal structure has formerly been tried. Multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist. Perhaps almost as many forms of plants might have been found in the fields, as figures of plants can be delineated upon paper. A countless variety of animals might have existed which do not exist. Upon the supposition here stated, we should see unicorns and mermaids, sylphs and centaurs; the fancies of painters and the fables of poets realized by examples. Or, if it be alleged that these may transgress the limits of possible life and propagation, we might, at least, have notions of human beings without nails upon their fingers, with more or fewer fingers and toes than ten, some with one eye, others with one ear, with one nostril, or without the sense of smelling at all. All these, and a thousand other imaginable varieties, might live and propagate. We may modify any one species many different ways, all consistent with life, and with the actions necessary to preservation, although affording different degrees of convenience and enjoyment to the animal. And if we carry these modifications through the different species which are known to subsist, their number would be incalculable. No reason can be given why; if these deperdits ever existed, they have now disappeared. Yet, if all possible existences have been tried, they must have formed part of the catalogue.

But moreover, the division of organized substances

into animals and vegatables, and the distribution and sub-distribution of each into genera and species, which distribution is not an arbitrary act of the mind, but is founded in the order which prevails in external nature, appear to me to contradict the supposition of the present world being the remains of an indefinite variety of existences; of variety which rejects all plan. The hypothesis teaches, that every possible variety of being hath, at one time or other, found its way into existence (by what cause or in what manner is not said), and that those which were badly formed, perished; but how or why those which survived should be cast, as we see that plants and animals are cast, into regular classes, the hypothesis does not explain; or rather the hypothesis is inconsistent with this phenomenon.

The hypothesis, indeed, is hardly deserving of the consideration which we have given to it. What should we think of the man, who, because we had never ourselves seen watches, telescopes, stocking-mills, steam-engines, &c. made; knew not how they were made; or could prove by testimony when they were made, or by whom;—would have us believe that these machines, instead of deriving their curious structures from the thought and design of their inventors and contrivers, in truth, derive them from no other origin than this; that, a mass of metals, and other materials having run, when melted, into all possible figures, and combined themselves in all possible forms, and shapes, and proportions; these things which we see, are what were left from the accident, as best worth preserving; and, as such, are become the remaining stock of a magazine, which at one time or other, has, by this means, contained every mechanism, useful and useless, convenient and inconvenient, into which such

like materials could be thrown? I cannot distinguish the hypothesis as applied to the works of nature, from this solution, which no one would accept, as applied to a collection of machines.

V. To the marks of contrivance discoverable in animal bodies, and to the argument deduced from them in proof of design, and of a designing Creator, this turn is sometimes attempted to be given, viz. that the parts were not intended for the use, but that the use arose out of the parts. This distinction is intelligible. A cabinet-maker rubs his mahogany with fish-skin; yet it would be too much to assert that the skin of the dog-fish was made rough and granulated on purpose for the polishing of wood, and the use of cabinet-makers. Therefore the distinction is intelligible. But I think that there is very little place for it in the works of nature. When roundly and generally affirmed of them, as it hath sometimes been, it amounts to such another stretch of assertion, as it would be to say, that all the implements of the cabinet-maker's workshop, as well as his fish-skin, were substances accidentally configurated, which he had picked up, and converted to his use; that his adzes, saws, planes, and gimlets, were not made, as we suppose, to hew, cut, smooth, shape out, or bore wood with; but that, these things being made, no matter with what design, or whether with any, the cabinet-maker perceived that they were applicable to his purpose, and turned them to account.

But, again; so far as this solution is attempted to be applied to those parts of animals, the action of which does not depend upon the will of the animal, it is fraught with still more evident absurdity. Is it possible to believe that the eye was formed without any regard to vision;

that it was the animal itself which found out, that, though formed with no such intention, it would serve to see with; and that the use of the eye, as an organ of sight, resulted from this discovery, and the animal's application of it? The same question may be asked of the ear; the same of all the senses. None of the senses, fundamentally, depend upon the election of the animal; consequently neither upon his sagacity nor his experience. It is the impression which objects make upon them that constitutes their use. Under that impression he is passive. He may bring objects to the sense, or within its reach he may select these objects; but over the impression itself he has no power, or very little; and that properly is the sense.

Secondly, there are many parts of animal bodies which seem to depend upon the will of the animal in a greater degree than the senses do, and yet with respect to which this solution is equally unsatisfactory. If we apply the solution to the human body for instance, it forms itself into questions upon which no reasonable mind can doubt; such as, whether the teeth were made expressly for rhe mastication of food, the feet for walking, the hands for holding; or whether, these things being as they are, being in fact in the animal's possession, his own ingenuity taught him that they were convertible to these purposes, though no such purposes were contemplated in their formation.

All that there is of the appearance of reason in this way of considering the subject is, that, in some cases, the organization seems to determine the habits of the animal, and its choice, to a particular mode of life; which, in a certain sense, may be called "the use arising out of the part." Now to all the instances, in which there is

any place for this suggestion, it may be replied, that the organization determines the animal to habits beneficial and salutary to itself; and that this effect would not be seen so regularly to follow, if the several organizations did not bear a concerted and contrived relation to the substances by which the animal was surrounded. They would, otherwise, be capacities without objects; powers without employment. The web foot determines, you say, the duck to swim: but what would that avail, if there were no water to swim in? The strong, hooked bill, and sharp talons, of one species of bird, determine it to prey upon animals; the soft straight bill, and weak claws of another species, determine it to pick up seeds: but neither determination could take effect in providing for the sustenance of the birds, if animal bodies and vegetable seeds did not lie within their reach. The peculiar conformation of the bill, and tongue, and claws of the woodpecker, determines that bird to search for his food amongst the insects lodged behind the bark, or in the wood, of decayed trees; but what would this profit him if there were no trees, no decayed trees, no insects lodged under their bark, or in their trunk? The proboscis with which the bee is furnished, determines him to seek for honey; but what would that signify, if flowers supplied none? Faculties thrown down upon animals at random, and without reference to the objects amidst which they are placed, would not produce to them the services and benefits which we see: and if there be that reference, then there is intention.

Lastly, the solution fails entirely when applied to plants. The parts of plants answer their uses, without any concurrence from the will or choice of the plant.

VI. Others have chosen to refer every thing to a *prin-*

ciple of order in nature. A principle of order is the word; but what is meant by a principle of order, as different from an intelligent Creator, has not been explained either by definition or example: and, without such explanation, it should seem to be a mere substitution of words for reasons, names for causes. Order itself is only the adaptation of means to an end; a principle of order, therefore, can only signify the mind and intention which so adapts them. Or were it capable of being explained in any other sense, is there any experience, any analogy to sustain it? Was a watch ever produced by a principle of order? and why might not a watch be so produced as well as an eye?

Furthermore, a principle of order, acting blindly and without choice, is negatived by the observation, that order is not universal; which it would be, if it issued from a constant and necessary principle; nor indiscriminate, which it would be, if it issued from an unintelligent principle. Where order is wanted, there we find it; where order is not wanted, i. e. where, if it prevailed, it would be useless, there we do not find it. In the structure of the eye (for we adhere to our example), in the figure and position of its several parts, the most exact order is maintained. In the forms of rocks and mountains, in the lines which bound the coasts of continents and islands, in the shape of bays and promontories, no order whatever is perceived, because it would have been superfluous. No useful purpose would have arisen from moulding rocks and mountains into regular solids, bounding the channel of the ocean by geometrical curves, or from the map of the world resembling a table of diagrams in Euclid's Elements, or Simpson's Conic Sections.

VII. Lastly, the confidence which we place in our observations upon the works of nature, in the marks which we discover of contrivance, choice, and design, and in our reasoning upon the proofs afforded us, ought not to be shaken, as it is sometimes attempted to be done by bringing forward to our view our own ignorance, or rather, the general imperfection of our knowledge of nature. Nor, in many cases, ought this consideration to affect us, even when it respects some parts of the subject immediately under our notice. True fortitude of understanding consists in not suffering what we know to be disturbed by what we do not know. If we perceive an useful end, and means adapted to that end, we perceive enough for our conclusion. If these things be clear, no matter what is obscure. The argument is finished. For instance; if the utility of vision to the animal which enjoys it, and the adaptation of the *eye* to this office be evident and certain (and I can mention nothing that is more so,) ought it to prejudice the inference which we draw from these premises, that we cannot explain the use of the spleen? Nay more; if there be parts of the eye, viz. the cornea, the crystalline, the retina, in their substance, figure, and position, manifestly suited to the formation of an image by the refraction of rays of light, at least as manifestly as the glasses and tubes of a dioptric telescope are suited to that purpose, it concerns not the proof which these afford of design and of a designer, that there may perhaps be other parts, certain muscles, for instance, or nerves, in the same eye, of the agency or effect of which we can give no account; any more than we should be inclined to doubt, or ought to doubt, about the construction of a telescope, viz. for what purpose it was constructed, or whether it were constructed at all,

because there belonged to it certain screws and pins, the use or action of which we did not comprehend. I take it to be a general way of infusing doubts and scruples into the mind, to recall to its own ignorance, its own imbecility; to tell us that upon these subjects we know little; that little imperfectly; or rather, that we know nothing properly about the matter. These suggestions so fall in with our consciousnesses, as sometimes to produce a general distrust of our faculties and our conclusions. But this is an unfounded jealousy. The uncertainty of one thing, does not necessarily affect the certainty of another thing. Our ignorance of many points need not suspend our assurance of a few. Before we yield, in any particular instance, to the scepticism which this sort of insinuation would induce, we ought accurately to ascertain, whether our ignorance or doubt concern those precise points upon which our conclusion rests. Other points are nothing. Our ignorance of other points may be of no consequence to these; though they be points, in various respects, of great importance. A just reasoner removes from his consideration, not only what he knows, but what he does not know, touching matters not strictly connected with his argument, i. e. not forming the very steps of his deduction: beyond these, his knowledge and his ignorance are alike irrelative.

CHAPTER VI.

THE ARGUMENT CUMULATIVE.

WERE there no example in the world of contrivance except that of the *eye*, it would be alone sufficient to support the conclusion which we draw from it, as to the necessity of an intelligent Creator. It could never be got rid of: because it could not be accounted for by any other supposition, which did not contradict all the principles we possess of knowledge; the principles according to which, things do, as often as they can be brought to the test of experience, turn out to be true or false. Its coats and humours, constructed, as the lenses of a telescope are constructed, for the refraction of rays of light to a point, which forms the proper action of the organ; the provision in its muscular tendons for turning its pupil to the object, similar to that which is given to the telescope by screws, and upon which power of direction in the eye, the exercise of its office as an optical instrument depends; the further provision for its defence, for its constant lubricity and moisture, which we see in its socket and its lids, in its glands for the secretion of the matter of tears, its outlet or communication with the nose for carrying off the liquid after the eye is washed with it; these provisions compose altogether an apparatus, a system of parts, a preparation of means, so manifest in their design, so exquisite in their contrivance, so successful in their issue, so precious, and so infinitely beneficial in their use, as, in my

opinion, to bear down all doubt that can be raised upon the subject. And what I wish, under the title of the present chapter, to observe, is, that, if other parts of nature were inaccessible to our enquiries, or even if other parts of nature presented nothing to our examination but disorder and confusion, the validity of this example would remain the same. If there were but one watch in the world, it would not be less certain that it had a maker. If we had never in our lives seen but one single kind of hydraulic machine; yet, if of that one kind we understood the mechanism and use, we should be as perfectly assured that it proceeded from the hand, and thought, and skill of a workman, as if we visited a museum of the arts, and saw collected there twenty different kinds of machines for drawing water, or a thousand different kinds for other purposes. Of this point each machine is a proof, independently of all the rest. So it is with the evidences of a divine agency. The proof is not a conclusion, which lies at the end of a chain of reasoning, of which chain each instance of contrivance is only a link, and of which, if one link fail, the whole falls; but it is an argument separately supplied by every separate example. An error in stating an example affects only that example. The argument is cumulative in the fullest sense of that term. The eye proves it without the ear; the ear without the eye. The proof in each example is complete; for when the design of the part, and the conduciveness of its structure to that design, is shown, the mind may set itself at rest; no future consideration can detract any thing from the force of the example.

CHAPTER VII.

OF THE MECHANICAL AND IMMECHANICAL PARTS AND FUNCTIONS OF ANIMALS AND VEGETABLES.

IT is not that *every* part of an animal or vegetable has not proceeded from a contriving mind; or that every part is not constructed with a view to its proper end and purpose, according to the laws belonging to, and governing, the substance or the action made use of in that part; or that each part is not so constructed, as to effectuate its purpose whilst it operates according to these laws; but it is, because the laws themselves are not in all cases equally understood; or, what amounts to nearly the same thing, or not equally exemplified in more simple processes, and more simple machines; that we lay down the distinction, here proposed, between the mechanical parts, and other parts, of animals and vegetables.

For instance; the principle of muscular motion, viz. upon what cause the swelling of the belly of the muscle, and consequent contraction of its tendons, either by an act of the will or by involuntary irritation, depends, is wholly unknown to us. The substance employed, whether it be fluid, gaseous, elastic, electrical, or none of these, or nothing resembling these, is also unknown to us; of course the laws belonging to that substance, and which regulate its action, are unknown to us. We see nothing similar to this contraction in any machine which we can make, or any process which we can execute. So far (it is confessed) we are in ignorance; but no further. This

power and principle, from whatever cause it proceeds, being assumed, the collocation of the fibres to receive the principle, the disposition of the muscles for the use and application of the power, is mechanical; and is as intelligible as the adjustment of the wires and strings by which a puppet is moved. We see, therefore, as far as respects the subject before us, what is not mechanical in the animal frame, and what is. The nervous influence (for we are often obliged to give names to things which we know little about)—I say the nervous influence, by which the belly or middle of the muscle is swelled, is not mechanical. The utility of the effect we perceive; the means, or the preparation of means, by which it is produced, we do not. But obscurity as to the origin of muscular motion brings no doubtfulness into our observations upon the sequel of the process. Which observations relate, 1st, to the constitution of the muscle; in consequence of which constitution, the swelling of the belly or middle part is necessarily and mechanically followed by a contraction of the tendons: 2dly, to the number and variety of the muscles, and the corresponding number and variety of useful powers which they supply to the animal; which is astonishingly great: 3dly, to the judicious (if we may be permitted to use that term, in speaking of the author, or of the works, of nature,) to the wise and well-contrived disposition of each muscle for its specific purpose; for moving the joint this way, and that way, and the other way; for pulling and drawing the part to which it is attached, in a determinate and particular direction; which is a mechanical operation, exemplified in a multitude of instances. To mention only one; the tendon of the trochlear muscle of the eye, to the end that it may draw in the line required, is passed through a cartilaginous ring, at which it is

reverted, exactly in the same manner as a rope in a ship is carried over or round a stay, in order to make it pull in the direction which is wanted. All this, as we have said, is mechanical; and is as accessible to inspection, as capable of being ascertained, as the mechanism of the automaton in the Strand. Suppose the automaton to be put in motion by a magnet (which is probable,) it will supply us with a comparison very apt for our present purpose. Of the magnetic effluvium we know perhaps as little as we do of the nervous fluid. But magnetic attraction being assumed (it signifies nothing from what cause it proceeds,) we can trace, or there can be pointed out to us, with perfect clearness and certainty, the mechanism, viz. the steel bars, the wheels, the joints, the wires, by which the motion so much admired is communicated to the fingers of the image: and to make any obscurity, or difficulty, or controversy in the doctrine of magnetism, an objection to our knowledge or our certainty concerning the contrivance, or the marks of contrivance, displayed in the automaton, would be exactly the same thing, as it is to make our ignorance (which we acknowledge) of the cause of nervous agency, or even of the substance and structure of the nerves themselves, a ground of question or suspicion as to the reasoning which we institute concerning the mechanical part of our frame. That an animal is a machine, is a proposition, neither correctly true, nor wholly false. The distinction which we have been discussing will serve to show how far the comparison, which this expression implies, holds; and wherein it fails. And, whether the distinction be thought of importance or not, it is certainly of importance to remember, that there is neither truth nor justice in endeavouring to bring a cloud over our understandings, or a distrust into our reasonings upon this sub-

ject, by suggesting that we know nothing of voluntary motion, of irritability, of the principle of life, of sensation, of animal heat, upon all which the animal functions depend; for our ignorance of these parts of the animal frame concerns not at all our knowledge of the mechanical parts of the same frame. I contend, therefore, that there is mechanism in animals; that this mechanism is as properly such, as it is in machines made by art; that this mechanism is intelligible and certain; that it is not the less so, because it often begins or terminates with something which is not mechanical; that, whenever it is intelligible and certain, it demonstrates intention and contrivance, as well in the works of nature as in those of art; and that it is the best demonstration which either can afford.

But, whilst I contend for these propositions, I do not exclude myself from asserting that there may be, and that there are, other cases, in which, although we cannot exhibit mechanism, or prove indeed that mechanism is employed, we want not sufficient evidence to conduct us to the same conclusion.

There is what may be called the *chymical* part of our frame; of which, by reason of the imperfection of our chymistry, we can attain to no distinct knowledge: I mean, not to a knowledge, either in degree or kind, similar to that which we possess of the mechanical part of our frame. It does not, therefore, afford the same species of argument as that which mechanism affords; and yet it may afford an argument in a high degree satisfactory. The *gastric juice*, or the liquor which digests the food in the stomachs of animals, is of this class. Of all menstrua it is the most universal. In the human stomach, for instance, consider what a variety of strange substances, and how widely different from one another, it, in a few hours,

reduces to one uniform pulp, milk, or mucilage. It seizes upon every thing, it dissolves the texture of almost every thing, that comes in its way. The flesh of, perhaps, all animals; the seeds and fruits of the greatest number of plants; the roots and stalks and leaves of many, hard and tough as they are, yield to its powerful pervasion. The change wrought by it is different from any chymical solution which we can produce, or with which we are acquainted, in this respect as well as many others, that, in our chymistry, particular menstrua act only upon particular substances. Consider moreover, that this fluid, stronger in its operation than a caustic alkali or mineral acid, than red precipitate or aqua fortis itself, is nevertheless as mild, and bland, and inoffensive to the touch or taste, as saliva or gum water, which it much resembles. Consider, I say, these several properties of the digestive organ, and of the juice with which it is supplied, or rather with which it is made to supply itself, and you will confess it to be entitled to a name, which it has sometimes received, that of "the chymical wonder of animal nature."

Still we are ignorant of the composition of this fluid, and of the mode of its action; by which is meant that we are not capable, as we are in the mechanical part of our frame, of collating it with the operations of art. And this I call the imperfection of our chymistry; for, should the time ever arrive, which is not perhaps to be despaired of, when we can compound ingredients, so as to form a solvent, which will act in the manner in which the gastric juice acts, we may be able to ascertain the chymical principles upon which its efficacy depends, as well as from what part, and by what concoction, in the human body, these principles are generated and derived.

In the meantime, ought that, which is in truth the de-

fest of our chemistry, to hinder us from acquiescing in the inference, which a production of nature, by its place, its properties, its action, its surprising efficacy, its invaluable use, authorises us to draw in respect of a creative design?

Another most subtle and curious function of animal bodies is secretion. This function is semi-chymical and semi-mechanical; exceedingly important and diversified in its effects, but obscure in its process and in its apparatus. The importance of the secretory organs is but too well attested by the diseases, which an excessive, a deficient or a vitiated secretion is almost sure of producing. A single secretion being wrong, is enough to make life miserable; or sometimes to destroy it. Nor is the variety less than the importance. From one and the same blood (I speak of the human body) about twenty different fluids are separated; in their sensible properties, in taste, smell, colour, and consistency; the most unlike one another that is possible; thick, thin, salt, bitter, sweet: and if from our own we pass to other species of animals, we find amongst their secretions not only the most various, but the most opposite properties; the most nutritious aliment, the deadliest poison; the sweetest perfumes, the most fetid odours. Of these the greater part, as the gastric juice, the saliva, the bile, the slippery mucilage which lubricates the joints, the tears which moisten the eye, the wax which defends the ear, are, after they are secreted, made use of in the animal economy; are evidently subservient, and are actually contributing to the utilities of the animal itself. Other fluids seem to be separated only to be rejected. That this also is necessary (though why it was originally necessary, we cannot tell) is shown by the consequence of the separation being long suspended; which consequence is disease and death. Akin to secretion, if not

the same thing, is assimilation, by which one and the same blood is converted into bone, muscular flesh, nerves, membranes, tendons; things as different as the wood and iron, canvass and cordage, of which a ship with its furniture is composed. We have no operation of art wherewith exactly to compare all this, for no other reason perhaps than that all operations of art are exceeded by it. No chymical election, no chymical analysis or resolution of a substance into its constituent parts, no mechanical sifting or division, that we are acquainted with, in perfection or variety come up to animal secretion. Nevertheless the apparatus and process are obscure: not to say, absolutely concealed from our inquiries. In a few, and only a few instances, we can discern a little of the constitution of a gland. In the kidneys of large animals we can trace the emulgent artery dividing itself into an infinite number of branches; their extremities every where communicating with little round bodies, in the substance of which bodies the secret of the machinery seems to reside, for there the change is made. We can discern pipes laid from these round bodies towards the pelvis, which is a basin within the solid of the kidney. We can discern these pipes joining and collecting together into larger pipes; and when so collected, ending in innumerable papillæ, through which the secreted fluid is continually oozing into its receptacle. This is all we know of the mechanism of a gland, even in the case in which it seems most capable of being investigated. Yet to pronounce that we know nothing of animal secretion, or nothing satisfactorily, and with that concise remark to dismiss the article from our argument, would be to dispose of the subject very hastily and very irrationally. For the purpose which we want, that of evincing intention, we know a great deal. And

what we know is this. We see the blood carried by a pipe, conduit, or duct, to the gland. We see an organized apparatus, be its construction or action what it will, which we call that gland. We see the blood, or part of the blood, after it has passed through and undergone the action of the gland, coming *from* it by an emulgent vein or artery, i. e. by another pipe or conduit. And we see also at the same time a new and specific fluid issuing from the same gland by its excretory duct, i. e. by a third pipe or conduit; which new fluid is in some cases discharged out of the body, in more cases retained within it, and there executing some important and intelligible office. Now supposing, or admitting, that we know nothing of the proper internal constitution of a gland, or of the mode of its acting upon the blood; then our situation is precisely like that of an unmechanical looker-on, who stands by a stocking-loom, a corn-mill, a carding-machine, or a threshing-machine at work, the fabric and mechanism of which, as well as all that passes within, is hidden from his sight by the outside case; or, if seen, would be too complicated for his uninformed, uninstructed understanding to comprehend. And what is that situation?—This spectator, ignorant as he is, sees at one end a material enter the machine, as unground grain the mill, raw cotton the carding-machine, sheaves of unthreshed corn the threshing-machine; and when he casts his eye to the other end of the apparatus, he sees the material issuing from it in a new state; and, what is more, in a state manifestly adapted to future uses; the grain in meal fit for the making of bread, the wool in rovings ready for spinning into threads, the sheaf in corn dressed for the mill. Is it necessary that this man, in order to be convinced, that design, that intention, that contrivance has been employed about the

machine, should be allowed to pull it in pieces; should be enabled to examine the parts separately; explore their action upon one another, or their operation, whether simultaneous or successive, upon the material which is presented to them? He may long to do this to gratify his curiosity; he may desire to do it to improve his theoretic knowledge; or he may have a more substantial reason for requesting it, if he happen, instead of a common visitor, to be a mill-wright by profession, or a person sometimes called in to repair such-like machines when out of order; but, for the purpose of ascertaining the existence of counsel and design in the formation of the machine, he wants no such intromission or priority. What he sees is sufficient. The effect upon the material, the change produced in it, the utility of that change for future applications, abundantly testify, be the concealed part of the machine or of its construction what it will, the hand and agency of a contriver. If any confirmation were wanting to the evidence which the animal secretions afford of design, it may be derived, as hath been already hinted, from their variety, and from their appropriation to their place and use. They all come from the same blood; they are all drawn off by glands; yet the produce is very different, and the difference exactly adapted to the work which is to be done, or the end to be answered. No account can be given of this without resorting to appointment. Why, for instance, is the saliva, which is diffused over the seat of taste, insipid, whilst so many others of the secretions, the urine, the tears, and the sweat, are salt? Why does the gland within the ear separate a viscid substance, which defends that passage: the gland in the upper angle of the eye, a thin brine, which washes the ball? Why is the synovia of the joints mucilaginous, the bile bitter, stimu-

lating, and soapy? Why does the juice which flows into the stomach, contain powers, which make that bowel, the great laboratory, as it is by its situation the recipient, of the materials of future nutrition? These are all fair questions; and no answer can be given to them, but what calls in intelligence and intention.

My object in the present chapter has been to teach three things: first, that it is a mistake to suppose, that, in reasoning from the appearances of nature, the imperfection of our knowledge proportionably affects the certainty of our conclusion; for in many cases it does not affect it at all: secondly, that the different parts of the animal frame may be classed and distributed, according to the degree of exactness with which we can compare them with works of art: thirdly, that the mechanical parts of our frame, or, those in which this comparison is most complete, although constituting, probably, the coarsest portions of nature's workmanship, are the properest to be alleged as proofs and specimens of design.

CHAPTER VIII.

OF MECHANICAL ARRANGEMENT IN THE HUMAN FRAME.

WE proceed, therefore, to propose certain examples taken out of this class; making choice of such, as amongst those which have come to our knowledge, appear to be the most striking, and the best underststood; but obliged, perhaps to postpone both these recomendations to a third, that of the example being capable of explanation without plates or figures, or technical language.

OF THE BONES.

I. I challenge any man to produce, in the joints and pivots of the most complicated, or the most flexible, machine, that was ever contrived, a construction more artificial, or more evidently artificial, than that which is seen in the vertebræ of the *human neck*. Two things were to be done. The head was to have the power of bending forward and backward, as in the act of nodding, stooping, looking upward or downward; and, at the same time, of turning itself round upon the body to a certain extent, the quadrant, we will say, or rather, perhaps, a hundred and twenty degrees of a circle. For these two purposes, two distinct contrivances are employed. First, the head rests immediately upon the uppermost of the vertebræ,

and is united to it by a *hinge* joint; upon which joint the head plays freely forward and backward, as far either way as is necessary, or as the ligaments allow: which was the first thing required. But then the rotatory motion is unprovided for. Therefore secondly, to make the head capable of this, a further mechanism is introduced; not between the head and the uppermost bone of the neck, where the hinge is, but between that bone, and the bone next underneath it. It is a mechanism resembling a *tenon and mortice*. This second, or uppermost bone but one, has what anatomists call a process, viz. a projection, somewhat similar, in size and shape, to a tooth; which tooth, entering a corresponding hole or socket in the bone above it, forms a pivot or axle, upon which that upper bone, together with the head which it supports, turns freely in a circle; and as far in the circle, as the attached muscles permit the head to turn. Thus are both motions perfect, without interfering with each other. When we nod the head we use the hinge joint, which lies between the head and the first bone of the neck. When we turn the head round, we use the tenon and mortice, which runs between the first bone of the neck and the second. We see the same contrivance, and the same principle, employed in the frame or mounting of a telescope. It is occasionally requisite, that the object end of the instrument be moved up and down, as well as horizontally, or equatorially. For the vertical motion there is a hinge upon which the telescope plays: for the horizontal or equatorial motion, an axis upon which the telescope and the hinge turn round together. And this is exactly the mechanism which is applied to the motion of the head: nor will any one here doubt of the existence of counsel

and design, except it be by that debility of mind, which can trust to its own reasonings in nothing.

We may add, that it was, on another acconnt also, expedient, that the motion of the head backward and forward should be performed upon the upper surface of the first vertebræ: for if the first vertebræ itself had bent forward, it would have brought the spinal marrow, at the very beginning of its course upon the point of the tooth.

II. Another mechanical contrivance, not unlike the last in its object, but different and original in its means, is seen in what anatomists call the *fore-arm*; that is, in the arm betweeen the elbow and the wrist. Here, for the perfect use of the limb, two motions are wanted; a motion at the elbow backward and forward, which is called a reciprocal motion; and a rotatory motion by which the palm of the hand, as occasion requires, may be turned upward. How is this managed? The fore-arm, it is well known, consists of two bones, lying along-side each other, but touching only towards the ends. One, and only one, of these bones, is joined to the cubit, or upper part of the arm, at the elbow; the other alone, to the hand at the wrist. The first, by means, at the elbow, of a hinge joint (which allows only of motion in the same plane,) swings backward and forward, carrying along with it the other bone, and the whole fore-arm. In the meantime, as often as there is occasion to turn the palm upward, that other bone, to which the hand is attached, rolls upon the first, by the help of a groove or hollow near each end of one bone, to which is fitted a corresponding prominence in the other. If both bones had been joined to the cubit or upper arm at the elbow, or both to the hand at the wrist,

the thing could not have been done. The first was to be at liberty at one end, and the second at the other: by which means the two actions may be performed together. The great bone, which carries the fore-arm, may be swinging upon its hinge at the elbow, at the very same time, that the lesser bone, which carries the hand, may be turning round it in the grooves. The management also of these grooves, or rather of the tubercles and grooves, is very observable. The two bones are called the radius and the ulna. Above, i. e. towards the elbow, a tubercle of the radius plays into a socket of the ulna; whilst below, i. e. towards the wrist, the radius finds the socket, and the ulna the tubercle. A single bone in the fore-arm, with a ball and socket joint at the elbow, which admits of motion in all directions, might, in some degree, have answered the purpose, of both moving the arm, and turning the hand. But how much better it is accomplished by the present mechanism, any person may convince himself, who puts the ease and quickness, with which he can shake his hand at the wrist circularly (moving likewise, if he pleases, his arm at the elbow at the same time,) in competition with the comparitively slow and laborious motion, with which his arm can be made to turn round at the shoulder, by the aid of a ball and socket joint.

III. The *spine* or back bone is a chain of joints of very wonderful construction. Various, difficult, and almost inconsistent offices were to be executed by the same instrument. It was to be firm, yet flexible (now I know no chain made by art, which is both these; for by firmness I mean, not only strength, but stability;) *firm*, to support the erect position of the body; *flexible*, to allow of bending the trunk in all degrees of curvature. It was further also, which is another, and quite a distinct purpose from

the rest, to become a pipe or conduit for the safe conveyance from the brain of the most important fluid of the animal frame, that, namely, upon which all voluntary motion depends, the spinal marrow; a substance, not only of the first necessity to action, if not to life, but of a nature so delicate and tender, so susceptible and so impatient of injury, as that any unusual pressure upon it, or any considerable obstruction of its course, is followed by paralysis or death. Now the spine was not only to furnish the main trunk for the passage of the medullary substance from the brain, but to give out, in the course of its progress, small pipes therefrom, which, being afterwards indefinitely subdivided, might, under the name of nerves, distribute this exquisite supply to every part of the body. The same spine was also to serve another use not less wanted than the preceding, viz. to afford a fulcrum, stay, or basis (or more properly speaking a series of these) for the insertion of the muscles which are spread over the trunk of the body; in which trunk there are not, as in the limbs, cylindrical bones, to which they can be fastened, and likewise, which is a similar use, to furnish a support for the ends of the ribs to rest upon.

Bespeak of a workman a piece of mechanism which shall comprise all these purposes, and let him set about to contrive it let him try his skill upon it; let him feel the difficulty of accomplishing the task, before he be told how the same thing is effected in the animal frame. Nothing will enable him to judge so well of the wisdom which has been employed: nothing will dispose him to think of it so truly. First, for the firmness, yet flexibility, of the spine, it is composed of a great number of bones (in the human subject of twenty-four) joined to one another, and compacted together, by broad bases. The breadth of the

bases upon which the parts severally rest, and the closeness of the junction, give to the chain its firmness and stability; the number of parts, and consequent frequency of joints, its flexibility. Which flexibility, we may also observe, varies in different parts of the chain: is least in the back, where strength more than flexure is wanted; greater in the loins, which it is necessary should be more supple than the back; and greatest of all in the neck, for the free motion of the head. Then, secondly, in order to afford a passage for the descent of the medullary substance, each of these bones is bored through in the middle in such a manner, as that, when put together, the hole in one bone falls into a line, and corresponds, with the holes in the two bones contiguous to it. By which means, the perforated pieces, when joined, form an entire, close, uninterrupted channel: at least whilst the spine is upright and at rest. But, as a settled posture is inconsistent with its use, a great difficulty still remained, which was to prevent the vertebræ shifting upon one another, so as to break the line of the canal as often as the body moves or twists; or the joints gaping externally, whenever the body is bent forward, and the spine, thereupon, made to take the form of a bow. These dangers, which are mechanical, are mechanically provided against. The vertebræ, by means of their processes and projections, and of the articulations which some of these form with one another, at their extremities, are so locked in and confined, as to maintain, in what are called the bodies or broad surfaces of the bones, the relative position nearly unaltered; and to throw the change and the pressure, produced by flexion, almost entirely upon the intervening cartilages, the springiness and yielding nature of whose substance admits of all the motion which is necessary to be performed upon them,

without any chasm being produced by a separation of the parts. I say of all the motion which is necessary; for, although we bend our backs to every degree of inclination, the motion of each vertebra is very small: such is the advantage which we receive from the chain being composed of so many links, the spine of so many bones. Had it consisted of three or four bones only, in bending the body the spinal marrow must have been bruised at every angle. The reader need not be told that these intervening cartilages are gristles; and he may see them in perfection in a loin of veal. Their form also favours the same intention. They are thicker before than behind, so that, when we stoop forward, the compressible substance of the cartilage, yielding in its thicker and anterior part to the force which squeezes it, brings the surfaces of the adjoining vertebræ nearer to the being parallel with one another than they were before, instead of increasing the inclination of their planes, which must have occasioned a fissure or opening between them. Thirdly, for, the medullary canal giving out in its course, and in a convenient order, a supply of nerves to different parts of the body, notches are made in the upper and lower edge of every vertebra; two on each edge; equi-distant on each side from the middle line of the back. When the vertebræ are put together, these notches, exactly fitting, form small holes, through which the nerves, at each articulation, issue out in pairs, in order to send their branches to every part of the body, and with an equal bounty to both sides of the body. The fourth purpose assigned to the same instrument, is the insertion of the bases of the muscles, and the support of the ends of the ribs: and for this fourth purpose, especially the former part of it, a figure, specifically suited to the design, and unnecessary for the other pur-

poses, is given to the constituent bones. Whilst they are plain, and round, and smooth towards the front, where any roughness or projection might have wounded the adjacent viscera, they run out, behind, and on each side, into long processes, to which processes the muscles necessary to the motions of the trunk are fixed; and fixed with such art, that, whilst the vertebræ supply a basis for the muscles, the muscles help to keep these bones in their position, or by their tendons to tie them together.

That most important, however, and general property, viz. the strength of the compages, and the security against luxation, was to be still more specially consulted; for where so many joints were concerned, and where, in every one, derangement would have been fatal, it became a subject of studious precaution. For this purpose, the vertebræ are articulated, that is, the moveable joints between them are formed, by means of those projections of their substance, which we have mentioned under the name of processes; and these so lock in with, and overwrap, one another, as to secure the body of the vertebræ, not only from accidentally slipping, but even from being pushed out of its place, by any violence short of that which would break the bone. I have often remarked and admired this structure in the chine of a hare. In this, as in many instances, a plain observer of the animal economy may spare himself the disgust of being present at human dissections, and yet learn enough for his information and satisfaction, by even examining the bones of the animals which come upon his table. Let him take, for example, into his hands, a piece of the clean-picked bone of a hare's back; consisting, we will suppose, of three vertebræ. He will find the middle bone of the three, so implicated by means of its projections or processes, with the bone on each side of

it, that no pressure which he can use, will force it out of its place between them. It will give way neither forward, nor backward, nor on either side. In whichever direction he pushes, he perceives, in the form, or junction, or overlapping of the bones, an impediment opposed to his attempt; a check and guard against dislocation. In one part of the spine, he will find a still further fortifying expedient, in the mode according to which the ribs are annexed to the spine. Each rib rests upon two vertebræ. That is the thing to be remarked, and any one may remark it in carving a neck of mutton. The manner of it is this: the end of the rib is divided by a middle ridge into two surfaces, which surfaces are joined to the bodies of two contiguous vertebræ, the ridge applying itself to the intervening cartilage. Now this is the very contrivance which is employed in the famous iron bridge at my door at Bishop-Wearmouth; and for the same purpose of stability; viz. the cheeks of the bars, which pass between the arches, ride across the joints, by which the pieces composing each arch are united. Each cross bar rests upon two of these pieces at their place of junction; and by that position resists, at least in one direction, any tendency in either piece to slip out of its place. Thus perfectly, by one means or the other, is the danger of slipping laterally, or of being drawn aside out of the *line* of the back provided against: and, to withstand the bones being pulled asunder longitudinally, or in the direction of the line, a stong membrane runs from one end of the chain to the other, sufficient to resist any force which is ever likely to act in the direction of the back, or parallel to it, and consequently to secure the whole combination in their places. The general result is, that not only the motions of the human body necessary for the ordinary offices of life are

performed with safety, but that it is an accident hardly ever heard of, that even the gesticulations of a harlequin distort his spine.

Upon the whole, and as a guide to those who may be inclined to carry the consideration of this subject further, there are three views under which the spine ought to be regarded, and in all which it cannot fail to excite our admiration. These views relate to its articulations, its ligaments, and its perforation; and to the corresponding advantages which the body derives from it, for action, for strength, and for that, which is essential to every part, a secure communication with the brain.

The structure of the spine is not in general different in different animals. In the serpent tribe, however, it is considerably varied; but with a strict reference to the conveniency of the animal. For, whereas in quadrupeds the number of vertebræ is from thirty to forty, in the serpent it is nearly one hundred and fifty: whereas in men and quadrupeds the surfaces of the bones are flat, and these flat surfaces laid one against the other, and bound tight by sinews; in the serpent, the bones play one within another like a ball and socket,* so that they have a free motion upon one another in every direction: that is to say, in men and quadrupeds firmness is more consulted; in serpents, pliancy.

Yet even pliancy is not obtained at the expense of safety. The backbone of a serpent, for coherence and flexibility, is one of the most curious pieces of animal mechanism, with which we are acquainted. The chain of a watch (I mean the chain which passes between the spring barrel and the fusee) which aims at the same properties, is

* Der. Phys. Theol. p. 396.

but a bungling piece of workmanship in comparison with that of which we speak.

IV. The reciprocal enlargement and contraction of the *chest* to allow for the play of the lungs, depends upon a simple yet beautiful mechanical contrivance, referable to the structure of the bones which inclose it. The ribs are articulated to the back bone, or rather to its side projection, *obliquely;* that is, in their natural position they bend or slope from the place of articulation downwards. But the basis upon which they rest at this end being fixed, the consequence of the obliquity, or the inclination downwards, is, that, when they come to move, whatever pulls the ribs upwards, necessarily, at the same time, draws them out; and that, whilst the ribs are brought to a right angle with the spine behind, the sternum, or part of the chest to which they are attached in front, is thrust forward. The simple action, therefore, of the elevating muscles does the business; whereas, if the ribs had been articulated with the bodies of the vertebræ at right angles, the cavity of the thorax could never have been further enlarged by a change of their position. If each rib had been a rigid bone, articulated at both ends to fixed bases, the whole chest had been immovable. Keill has observed, that the breast-bone in an easy inspiration, is thrust out one tenth of an inch; and he calculates that this, added to what is gained to the space within the chest by the flattening or descent of the diaphragm, leaves room for forty-two cubic inches of air to enter at every drawing in of the breath. When there is a necessity for a deeper and more laborious inspiration, the enlargement of the capacity of the chest may be so increased by effort, as that the lungs may be distended with seventy or a hundred such cubic inches.* The tho-

* Anat. p. 229.

rax, says Schelhammer, forms a kind of bellows, such as never have been, nor probably will be made by any artificer.

V. The *patella*, or knee-pan, is a curious little bone; in its form and office unlike any other bone of the body. It is circular; the size of a crown piece; pretty thick; a little convex on both sides, and covered with a smooth cartilage. It lies upon the front of the knee; and the powerful tendons, by which the leg is brought forward, pass through it (or rather it makes a part of their continuation) from their origin in the thigh to their insertion in the tibia. It protects both the tendon and the joint from any injury which either might suffer, by the rubbing of one against the other, or by the pressure of unequal surfaces. It also gives to the tendons a very considerable mechanical advantage by altering the line of their direction, and by advancing it further out from the centre of motion; and this upon the principles of the resolution of force, upon which principles all machinery is founded. These are its uses. But what is most observable in it is, that it appears to be supplemental, as it were, to the frame; added as it should almost seem, afterward; not quite necessary, but very convenient. It is separate from the other bones; that is, it is not connected with any other bones by the common mode of union. It is soft, or hardly formed, in infancy; and produced by an ossification, of the inception or progress of which, no account can be given from the structure or exercise of the part.

VI. The *shoulder-blade* is in some material respects, a very singular bone; it appearing to be made so expressly for its own purpose, and so independently of every other reason. In such quadrupeds as have no collar bones which are by far the greater number, the shoulder-b[l]

has no bony communication with the trunk, either by a joint, or process, or in any other way. It does not grow to, or out of, any other bone of the trunk. It does not apply to any other bone of the trunk (I know not whether this be true of any second bone in the body, except perhaps the os hyoides.) In strictness, it forms no part of the skeleton. It is bedded in the flesh; attached only to the muscles. It is no other than a foundation bone for the arm, laid in, separate, as it were, and distinct, from the general ossification. The lower limbs connect themselves at the hip with bones which form a part of the skeleton; but, this connection, in the upper limbs, being wanted, a basis whereupon the arm might be articulated, was to be supplied by a detached ossification for the purpose.

I. The above are a few examples of bones made remarkable by their configuration: but to almost all the bones belong *joints;* and in these, still more clearly than in the form or shape of the bones themselves, are seen both contrivance and contriving wisdom. Every joint is a curiosity, and is also strictly mechanical. There is the hinge joint, and the mortice and tenon joint; each as manifestly such, and as accurately defined, as any which can be produced out of a cabinet-maker's shop. And one or the other prevails, as either is adapted to the motion which is wanted: e. g. a mortice and tenon, or ball and socket joint, is not required at the knee, the leg standing in need only of a motion backward and forward in the same plane, for which a hinge joint is sufficient: a mortice and tenon, or ball and socket joint, is wanted at the hip, that not only the progressive step may be provided for, but the interval between the limbs may be enlarged or contracted at pleasure. Now observe what would have been the inconvenience, i. e. both the superfluity and the defect of articulation

if the case had been inverted; if the ball and socket joint had been at the knee, and the hinge joint at the hip. The thighs must have been kept constantly together, and the legs have been loose and straddling. There would have been no use that we know of, in being able to turn the calves of the legs before: and there would have been great confinement by restraining the motion of the thighs to one plane. The disadvantage would not have been less, if the joints at the hip, and the knee had been both of the same sort; both balls and sockets, or both hinges: yet why, independently of utility, and of a Creator who consulted that utility, should the same bone (the thigh-bone) be rounded at one end, and channelled at the other?

The *hinge joint* is not formed by a bolt passing through the two parts of the hinge, and thus keeping them in their places; but by a different expedient. A strong, tough, parchment-like membrane, rising from the receiving bones, and inserted all round the received bones a little below their heads, incloses the joint on every side. This membrane ties, confines, and holds the ends of the bones together; keeping the corresponding parts of the joint, i. e. the relative convexities and concavities in close application to each other.

For the *ball and socket joint*, beside the membrane already described, there is in some important joints, as an additional security, a short, strong, yet flexible ligament, inserted, by one end into the head of the ball, by the other into the bottom of the cup; which ligament keeps the two parts of the joint so firmly in their place, that none of the motions which the limb naturally performs, none of the jerks and twists to which it is ordinarily liable, nothing less indeed than the utmost and the most unnatural violence, can pull them asunder. It is hardly indeed imagin-

able, how great a force is necessary, even to stretch, still more to break, this ligament; yet so flexible is it, as to oppose no impediment to the suppleness of the joint. By its situation also, it is inaccessible to injury from sharp edges. As it cannot be ruptured such is its strength; so it cannot be cut, except by an accident which would sever the limb. If I had been permitted to frame a proof of contrivance, such as might satisfy the most distrustful inquirer, I know not whether I could have chosen an example of mechanism more unequivocal, or more free from objection, than this ligament. Nothing can be more mechanical; nothing, however subservient to the safety, less capable of being generated by the action of the joint. I would particularly solicit the reader's attention to this provision, as it is found in the head of the thigh bone; to its strength, its structure, and its use. It is an instance upon which I lay my hand. One single fact, weighed by a mind in earnest, leaves oftentimes the deepest impression. For the purpose of addressing different understandings and different apprehensions, for the purpose of sentiment, for the purpose of exciting admiration of the Creator's works, we diversify our views, we multiply examples; but, for the purpose of strict argument, one clear instance is sufficient: and not only sufficient, but capable, perhaps, of generating a firmer assurance than what can arise from a divided attention

The *ginglymus*, or hinge joint, does not, it is manifest, admit of a ligament of the same kind with that of the ball and socket joint, but it is always fortified by the species of ligament of which it does admit. The strong, firm, investing membrane above described, accompanies it in every part: and, in particular joints, this membrane, which is properly a ligament, is considerably stronger on

the sides than either before or behind, in order that the convexities may play true in their concavities and not be subject to slip sideways, which is the chief danger; for the muscular tendons generally restrain the parts from going further than they ought to go in the plane of their motion. In the *knee*, which is a joint of this form and of great importance, there are superadded to the common provisions for the stability of the joint, two strong ligaments which cross each other, and cross each other in such a manner, as to secure the joint from being displaced in any assignable direction. "I think," says Cheselden, "that the knee cannot be completely dislocated without breaking the *cross* ligaments."* We can hardly help comparing this with the binding up of a fracture, where the fillet is almost always strapped across, for the sake of giving firmness and strength to the bandage.

Another no less important joint, and that also of the ginglymus sort, is the *ankle*; yet, though important, (in order, perhaps, to preserve the symmetry and lightness of the limb) *small*, and, on that account, more liable to injury. Now this joint is strengthened, i. e. is defended from dislocation, by two remarkable processes or prolongations of the bones of the leg, which process form the protuberances that we call the inner and outer ankle. It is part of each bone going down lower than the other part, and thereby overlapping the joint: so that, if the joint be in danger of slipping outward, it is curbed by the inner projection, i. e. that of the tibia; if inward, by the outer projection, i. e. that of the fibula. Between both, it is locked in its position. I know no account that can be given of this structure except its utility. Why should the

* Ches. Anat. ed. 7th, p. 45.

tibia terminate, at its lower extremity with a double end, and the fibula the same, but to barracade the joint on both sides by a continuation of part of the thickness of the bone over it?

The joint at the *shoulder* compared with the joint at the *hip*, though both ball and socket joints, discover a difference in their form and proportions, well suited to the different offices which the limbs have to execute. The cup or socket at the shoulder is much shallower and flatter than it is at the hip, and is also in part formed of cartilage set round the rim of the cup. The socket, into which the head of the thigh-bone is inserted, is deeper, and made of more solid materials. This agrees with the duties assigned to each part. The arm is an instrument of motion, principally, if not solely. Accordingly the shallowness of the socket at the shoulder, and the yieldingness of the cartilaginous substance with which its edge is set round, and which in fact composes a considerable part of its concavity, are excellently adapted for the allowance of a freer motion and a wider range; both which the arm wants. Whereas the lower limb, forming a part of the column of the body; having to support the body, as well as to be the means of its locomotion; firmness was to be consulted as well as action. With a capacity for motion, in all directions indeed, as at the shoulder, but not in any direction to the same extent as in the arm, was to be united stability, or resistance to dislocation. Hence the deeper excavation of the socket; and the presence of a less proportion of cartilage upon the edge.

The suppleness and pliability of the joints we every moment experience; and the *firmness* of animal articulation, the property we have hitherto been considering,

may be judged of from this single observation, that, at any given moment of time, there are millions of animal joints in complete repair and use, for one that is dislocated; and this, notwithstanding the contortions and wrenches to which the limbs of animals are continually subject.

II. The *joints*, or rather, the ends of the bones which form them, display also, in their configuration, another use. The nerves, blood vessels, and tendons, which are necessary to the life, or for the motion, of the limbs, must, it is evident, in their way from the trunk of the body to the place of their destination, travel over the moveable joints; and it is no less evident, that, in this part of their course, they will have, from sudden motions and from abrupt changes of curvature, to encounter the danger of compression, attrition, or laceration. To guard fibres so tender against consequences so injurious, their path is in those parts protected with peculiar care: and that by a provision in the figure of the bones themselves. The nerves which supply the *fore-arm*, especially the inferior cubital nerves, are at the elbow conducted, by a kind of covered way, between the condyls, or rather under the inner extuberances of the bone, which composes the upper part of the arm.* At the *knee* the extremity of the thigh-bone is divided by a sinus or cliff into two heads of protuberances; and these heads on the back part stand out beyond the cylinder of the bone. Through the hollow, which lies between the hind parts of these two heads, that is to say, under the ham, between the ham-strings, and within the concave recess of the bone formed by the extuberances on each side; in a word, along a defile, be-

* Ches. An. p. 255, ed. 7th.

tween rocks, pass the great vessels and nerves which go to the leg.† Who led these vessels by a road so defended and secure? In the joint at the *shoulder*, in the edge of the cup which receives the head of the bone, is a *notch*, which is joined or covered at the top with a ligament. Through this hole, thus guarded, the blood-vessels steal to their destination in the arm, instead of mounting over the edge of the concavity.‡

III. In all the joints, the end of the bones, which work against each other, are tipped with *gristle*. In the ball and socket joint, the cup is lined, and the ball capped with it. The smooth surface, the elastic and unfriable nature of cartilage, render it of all substances the properest for the place and purpose. I should therefore have pointed this out amongst the foremost of the provisions which have been made in the joints for the facilitating of their action, had it not been alledged, that cartillage in truth is only nascent or imperfect bone; and that the bone in these places is kept soft and imperfect, in consequence of a more complete and rigid ossification being prevented from taking place by the continual motion and rubbing of the surfaces. Which being so, what we represent as a designed advantage, is an unavoidable effect. I am far from being convinced that this is a true account of the fact; or that, if it were so, it answers the argument. To me, the surmounting of the ends of the bones with gristle, looks more like a plating with a different metal, than like the same metal kept in a different state by the action to which it is exposed. At all events we have a great particular benefit, though arising from a general constitution; but this last not being quite what my argument re-

† Ches. An. p. 35. ‡ Ib. 30.

quires, lest I should seem by applying the instance, to overrate its value, I have thought it fair to state the question which attends it.

IV. In some joints, very particularly in the knees, there are loose cartilages or gristles between the bones, and within the joint, so that the ends of the bones, instead of working upon one another, work upon the intermediate cartilages. Cheselden has observed,* that the contrivance of a loose ring is practised by mechanics, where the friction of the joints of any of their machines is great; as between the parts of crooked hinges of large gates, or under the head of the male screw of large vices. The cartilages of which we speak have very much of the form of these rings. The comparison moreover shows the reason why we find them in the knees rather than in other joints. It is an expedient, we have seen, which a mechanic resorts to, only when some strong and heavy work is to be done. So here the thigh bone has to achieve its motion at the knee, with the whole weight of the body pressing upon it, and often, as in rising from our seat, with the whole weight of the body to lift. It should seem also from Chesselden's account, that the slipping and sliding of the loose cartilages, though it be probable a small and obscure change, humoured the motion of the end of the thigh bone, under the particular configuration which was necessary to be given to it for the commodious action of the tendons; and which configuration requires what he calls a variable socket, that is, a concavity, the lines of which assume a different curvature in different inclinations of the bones.

V. We have now done with the configuration; but there is also in the joints, and that common to them all, another exquisite provision, manifestly adapted to their use, and

* Ches. An.[8] p. 13.

concerning which there can, I think, be no dispute; namely, the regular supply of a *mucilage*, more emollient and slippery than oil itself, which is constantly softening and lubricating the parts that rub upon each other, and thereby diminishing the effect of attrition in the highest possible degree. For the continual secretion of this important liniment, and for the feeding of the cavities of the joint with it, glands are fixed near each joint; the excretory ducts of which glands, dripping with their balsamic contents, hang loose like fringes within the cavity of the joints. A late improvement in what are called friction wheels, which consists of a mechanism so ordered, as to be regularly dropping oil into a box, which incloses the axis, the nave, and certain balls upon which the nave revolves, may be said, in some sort, to represent the contrivance in the animal joint; with this superiority, however, on the part of the joint, viz. that here, the oil is not only dropped, but *made*.

In considering the joints, there is nothing, perhaps, which ought to move our gratitude more than the reflection, *how well they wear*. A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without diminution of its agility: which is a long time for any thing to last; for any thing so much worked and exercised as the joints are. This durability I should attribute, in part, to the provision which is made for the preventing of wear and tear, first, by the polish of the cartilaginous surfaces, secondly, by the healing lubrication of the mucilage; and, in part, to that astonishing property of animal constitutions, assimilation, by which, in every portion of the body, let it consist of what it will, substance is restored, and waste repaired.

Moveable joints, I think, compose the curiosity of bones; but their union, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom. The teeth, especially the front teeth, are one bone fixed in another like a peg driven into a board. The sutures of the skull are like the edges of two saws clapped together, in such a manner as that the teeth of one enter the intervals of the other. We have sometimes one bone lapping over another, and planed down at the edges; sometimes also the thin lamella of one bone received into a narrow furrow of another. In all which varieties we seem to discover the same design, viz. firmness of juncture, without clumsiness in the seam.

CHAPTER IX.

OF THE MUSCLES.

MUSCLES, with their tendons, are the instruments by which animal motion is performed. It will be our business to point out instances in which, and properties with respect to which, the disposition of these muscles is as strictly mechanical, as that of the wires and strings of a puppet.

I. We may observe, what I believe is universal, an exact relation between the joint and the muscles which move it. Whatever motion, the joint by its mechanical construction, is capable of performing, that motion, the annexed muscles, by their position, are capable of producing. For example; if there be, as at the knee and elbow, a hinge joint, capable of motion only in the same plane, the leaders, as they are called, i. e. the muscular tendons, are placed in directions parallel to the bone, so as, by the contraction or relaxation o the muscles to which they belong, to produce that motion and no other. If these joints were capable of a freer motion there are no muscles to produce it. Whereas at the shoulder and the hip, where the ball and socket joint allows by its construction of rotatory or sweeping motion, tendons are placed in such a position, and pull in such a direction, as to produce the motion of which the joint admits. For instance, the sartorius or taylor's muscle, arising from the spine, running diagonally across the thigh, and taking hold of the inside of the main bone of the leg a little below the knee, enables us, by its contraction, to throw one leg and thigh over

the other; giving affect, at the same time, to the ball and socket joint at the hip, and the hinge joint at the knee.

There is, as we have seen, a specific mechanism in the bones for the rotatory motions of the head and hands: there is also in the oblique direction of the muscles belonging to them, a specific provision for the putting of this mechanism of the bones into action. And mark the consent of uses. The oblique muscles would have been inefficient without the articulation: the articulation would have been lost, without the oblique muscles. It may be proper however to observe with respect to the *head*, although I think it does not vary the case, that its oblique motions and inclinations are often motions in a *diagonal*, produced by the joint action of muscles lying in straight directions. But, whether the pull be single or combined; the articulation is always such, as to be capable of obeying the action of the muscles. The oblique muscles attached to the head, are likewise so disposed, as to be capable of steadying the globe, as well as of moving it. The head of a new-born infant is often obliged to be filleted up. After death the head drops and rolls in every direction. So that it is by the equilibre of the muscles, by the aid of a considerable and equipollent muscular force in constant exertion, that the head maintains its errect posture. The muscles here supply, what would otherwise be a great defect in the articulation: for the joint in the neck, although admirably adapted to the motion of the head, is insufficient for its support. It is not only by the means of a most curious structure of the bones that a man turns his head, but by virtue of an adjusted muscular power, that he even holds it up.

As another example of what we are illustrating, viz. conformity of use between the bones and the muscles,

it has been observed of the different vertebræ, that their processes are exactly proportioned to the quantity of motion which the other bones allow of, and which the respective muscles are capable of producing.

II. A muscle acts only by contraction. Its force is exerted in no other way. When the exertion ceases it relaxes itself, that is, it returns by relaxation to its former state; but without energy. This is the nature of the muscular fibre: and being so, it is evident that the reciprocal *energetic* motion of the limbs, by which we mean motion *with force* in opposite directions can only be produced by the instrumentality of opposite or antagonist muscles; of flexors and extensors answering to each other. For instance, the biceps and brachiæus *internus* muscles placed in the front part of the upper arm, by their contraction, bend the elbow; and with such degree of force, as the case requires, or the strength admits of. The relaxation of these muscles, after the effort, would merely let the fore-arm drop down. For the *back stroke*, therefore, and that the arm may not only bend at the elbow, but also extend and straighten itself with force, other muscles, the longus and brevis brachiæus *externus*, and the anconæus, placed on the hinder part of the arm, by their contractile twitch fetch back the fore-arm into a straight line with the cubit, with no less force than that with which it was bent out of it. The same thing obtains in all the limbs, and in every moveable part of the body. A finger is not bent and straightened, without the contraction of two muscles taking place. It is evident therefore, that the animal functions require that particular disposition of the muscles which we describe by the name of antagonist muscles. And they are accordingly so disposed. Every muscle is provided with an adversary. They act

like two sawers in a pit by an opposite pull: and nothing surely can more strongly indicate design and attention to an end than their being thus stationed; than this collocation. The nature of the muscular fibre being what it is, the purpose of the animal could be answered by no other. And not only the capacity for motion, but the aspect and symmetry of the body is preserved by the muscles being marshalled according to this order, e. g. the mouth is held in the middle of the face, and its angles kept in a state of exact correspondency, by two muscles drawing against, and balancing, each other. In a hemiplegia, when the muscle on one side is weakened, the muscle on the other side draws the mouth awry.

III. Another property of the muscles, which could only be the result of care, is their being almost universally so disposed, as not to obstruct or interfere with another's action. I know but one instance in which this impediment is perceived. We cannot easily swallow whilst we gape. This, I understand, is owing to the muscles employed in the act of deglutition, being so implicated with the muscles of the lower jaw, that whilst these last are contracted the former cannot act with freedom. The obstruction is, in this instance, attended with little inconveniency; but it shows what the effect is, where it does exist; and what loss of faculty there would be, if it were more frequent. Now when we reflect upon the number of muscles, not fewer than four hundred and forty-six in the human body, known and named,* how contiguous they lie to each other, in layers, as it were, over one another, crossing one another, sometimes embedded in one another, sometimes perforating one

* Keill's Anat. p. 295, ed. 3rd.

another, an arrangement, which leaves to each its liberty and its full play, must necessarily require meditation and counsel.

IV. The following is oftentimes the case with the muscles. Their action is wanted where their situation would be inconvenient. In which case the body of the muscle is placed in some commodious position at a distance, and made to communicate with the point of action, by slender strings or wires. If the muscles, which move the fingers, had been placed in the palm or back of the hand, they would have swelled that part to an awkward and clumsy thickness. The beauty, the proportions, of the part, would have been destroyed. They are therefore disposed in the arm, and even up to the elbow; and act by long tendons, strapped down at the wrist, and passing under the ligament to the fingers, and to the joints of the fingers, which they are severally to move. In like manner, the muscles which move the toes, and many of the joints of the foot, how gracefully are they disposed in the calf of the leg, instead of forming an unwieldly tumefaction in the foot itself? The observation may be repeated of the muscle which draws the nictitating membrane over the eye. Its office is in the front of the eye; but its body is lodged in the back part of the globe, where it lies safe, and where it incumbers nothing.

V. The great mechanical variety in the figure of the muscles may be thus stated. It appears to be a fixed law, that the contraction of a muscle shall be towards its centre. Therefore the subject for mechanism on each occasion is, so to modify the figure, and adjust the position, of the muscle, as to produce the motion required agreeably with this law. This can only be done by giv-

ing to different muscles, a diversity of configuration, suited to their several offices, and to their situation with respect to the work which they have to perform. On which account we find them under a multiplicity of forms, and attitudes; sometimes with double, sometimes with treble tendons, sometimes with none; sometimes one tendon to several muscles, at other times one muscle to several tendons. The shape of the organ is susceptible of an incalcuable variety, whilst the original property of the muscle, the law and line of its contraction, remains the same; and is simple. Herein the muscular system may be said to bear a perfect resemblance to our works of art. An artist does not alter the native quality of his materials, or their laws of action. He takes these as he finds them. His skill and ingenuity are employed in turning them, such as they are to his account, by giving to the parts of his machine a form and relation, in which these unalterable properties may operate to the production of the effects intended.

VI. The ejaculations can never too often be repeated. How many things must go right for us to be an hour at ease! How many more, to be vigourous and active! Yet vigour and activity are, in a vast plurality of instances, preserved in human bodies, notwithstanding that they depend upon so great a number of instruments of motion, and notwithstanding that the defect or disorder sometimes of a very small instrument, of a single pair, for instance, out of the four hundred and forty-six muscles which are employed, may be attended with grievous inconveniency. There is piety and good sense in the following observation taken out of the *Religious Philosopher*, "With much compassion," says this writer, "as

well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of these *two little muscles* that serve to lift up the eyelids, and so had almost lost the use of his sight; being forced, as long as this defect lasted, to shove up his eyelids every moment with his own hands!" In general we may remark how little those, who enjoy the perfect use of their organs, know the comprehensiveness of the blessing, the variety of their obligation. They perceive a result, but they think little of the multitude of concurrences and rectitudes which go to form it.

Besides these observations, which belong to the muscular organ as such, we may notice some advantages of structure which are more conspicuous in muscles of a certain class or description than in others. Thus,

I. The variety, quickness, and precision, of which muscular motion is capable, are seen, I think, in no part so remarkable as in the *tongue*. It is worth any man's while to watch the agility of his tongue; the wonderful promptitude with which it executes changes of position, and the perfect exactness. Each syllable of articulated sound requires for its utterance a specific action of the tongue, and of the parts adjacent to it. The disposition and configuration of the mouth, appertaining to every letter and word, is not only peculiar, but, if nicely and accurately attended to, perceptible to the sight; insomuch that curious persons have availed themselves of the circumstance to teach the deaf to speak, and to understand what is said by others. In the same person, and after his habit of speaking is formed, one, and only one, position of the parts, will produce a given articulate sound

correctly. How instantaneously are these positions assumed and dismissed; how numerous are the permutations, how various, yet how infallible? Arbitrary and antic variety is not the thing we admire; but variety obeying a rule, conducing to an effect, and commensurate with exigences infinitely diversified. I believe also that the anatomy of the tongue corresponds with these observations upon its activity. The muscles of the tongue are so numerous, and so implicated with one another, that they cannot be traced by the nicest dissection; nevertheless, which is a great perfection of the organ, neither the number, nor the complexity, nor what might seem to be, the entanglement of its fibres, in any wise impede its motion, or render the determination or success of its efforts uncertain.

I here intreat the reader's permission to step a little out of my way to consider *the parts of the mouth* in some of their other properties. It has been said, and that by an eminent physiologist, that, whenever nature attempts to work two or more purposes by one instrument, she does both or all imperfectly. Is this true of the tongue, regarded as an instrument of speech, and of taste; or regarded as an instrument of speech, of taste and of deglutition? So much otherwise, that many persons, that is to say, nine hundred and ninety-nine persons out of a thousand, by the instrumentality of this one organ, talk, and taste, and swallow, very well. In fact the constant warmth and moisture of the tongue, the thinness of the skin, the papillæ upon its surface, qualify this organ for its office of tasting, as much as its inextricable multiplicity of fibres do for the rapid movements which are necessary to

speech. Animals which feed upon grass, have their tongues covered with a perforated skin so as to admit the dissolved food to the papillæ underneath, which, in the mean time, remain defended from the rough action of the unbruised spiculæ.

There are brought together within the cavity of the mouth more distinct uses, and parts executing more distinct offices, than I think can be found lying so near to one another, or within the same compass, in any other portion of the body: viz. teeth of different shape, first for cutting, secondly for grinding: muscles, most artificially disposed for carrying on the compound motion of the lower jaw, half lateral and half vertical, by which the mill is worked; fountains of saliva, springing up in different parts of the cavity for the moistening of the food, whilst the mastication is going on: glands to feed the fountains: a muscular constriction of a very peculiar kind in the back part of the cavity, for the guiding of the prepared aliment into its passage towards the stomach, and in many cases for carrying it along that passage: for, although we may imagine this to be done simply by the weight of the food itself, it in truth is not so, even in the upright posture of the human neck? and most evidently is not the case with quadrupeds, with a horse, for instance, in which when pasturing, the food is thrust upward by muscular strength, instead of descending of its own accord.

In the meantime, and within the same cavity, is going on another business, altogether different from what is here described, that of respiration and speech. In addition, therefore, to all that has been mentioned, we have a passage opened, from this cavity to the lungs, for the admission of air, exclusively of every other substance: we have

muscles, some in the larynx, and without number in the tongue, for the purpose of modulating that air in its passage, with a variety, a compass, and precision, of which no other musical instrument is capable. And, lastly, which in my opinion crowns the whole as a piece of machinery, we have a specific contrivance for dividing the pneumatic part from the mechanical, and for preventing one set of action interfering with the other. Where various functions are united, the difficulty is to guard against the inconvenienoies of a too great complexity. In no apparatus put together by art, and for the purposes of art, do I know such multifarious uses so aptly combined, as in the natural organization of the human mouth; or where the structure, compared with the uses, is so simple. The mouth, with all these intentions to serve, is a single cavity; is one machine; with its parts neither crowded nor confused, and each unembarrassed by the rest: each at least at liberty in a degree sufficient for the end to be attained. If we cannot eat and sing at the same moment, we can eat one moment and sing the next; the respiration proceeding freely all the while.

There is one case, however, of this double office, and that of the *earliest* necessity, which the mouth alone could not perform; and that is, carrying on together the two actions of sucking and breathing. Another rout, therefore, is opened for the air, namely, through the nose, which lets the breath pass backward and forward, whilst the lips, in the act of sucking, are necessarily shut close upon the body, from which the nutriment is drawn. This is a circumstance, which always appeared to me worthy of notice. The nose would have been necessary, although it had not been the organ of smelling. The making it

the seat of a sense, was superadding a new use to a part already wanted: was taking a wise advantage of an antecedent and a constitutional necessity.

But to return to that which is the proper subject of the present section, the celerity and precision of muscular motion. These qualities may be particularly observed in the execution of many species of instrumental *music*, in which the changes produced by the hand of the musician, are exceedingly rapid; are exactly measured, even when most minute; and display, on the part of the muscles, an obedience of action, alike wonderful for its quickness and its correctness.

Or let a person only observe his own hand whilst he is *writing*; the number of muscles, which are brought to bear upon the pen; how the joint and adjusted operation of several tendons is concerned in every stroke, yet that five hundred such strokes, are drawn in a minute. Not a letter can be turned without more than one or two or three tendinous contractions, definite, both as to the choise of the tendon and as to the space through which the contraction moves, yet how currently does the work proceed? and when we look at it, how faithful have the muscles been to their duty, how true to the order which endeavour or habit hath inculcated? For let it be remembered, that, whilst a man's hand writing is the same, an exactitude of order is preserved whether he write well or ill. These two instances of music and writing, show not only the quickness and precision of muscular action, but the docility.

II Regarding the particular configuration of muscles, *sphincter* or circular muscles appear to me admirable pieces of mechanism. It is the muscular power most happily applied; the same quality of the muscular substance, but under a new modification. The circular disposition of the fibres is strictly mechanical; but, though the most mechanical, is not the only thing in sphincters which deserves our notice. The Regulated degree of contractile force with which they are endowed, sufficient for retention, yet vincible when requisite; together with their ordinary state of actual contraction, by means of which their dependence upon the will is not constant but occasional, gives to them a constitution of which the conveniency is inestimable. This their semi-voluntary character, is exactly such as suits with the wants and functions of the animal.

III. We may also, upon the subject of muscles, observe, that many of our most important actions are achieved by the combined help of different muscles. Frequently, a diagonal motion is produced, by the contraction of tendons, pulling in the direction of the sides of the parallelogram. This is the case, as hath been already noticed, with some of the oblique nutations of the head. Sometimes the number of co-operating muscles is very great. Dr. Nieuentyt, in the Leipzic Transactions, reckons up a hundred muscles that are employed every time we breathe: yet we take in, or let out, our breath, without reflecting what a work is thereby performed; what an apparatus is laid in of instruments for the service, and how many such contribute their assistance to the effect. Breathing with ease is a blessing of every moment: yet, of all others, it is that which we possess with the least conscious-

ness. A man in an asthma is the only man who knows how to estimate it.

IV. Mr. Home has observed,* that the most important and the most delicate actions are performed in the body by the smallest muscles: and he mentions, as his examples, the muscles which have been discovered in the iris of the eye and the drum of the ear. The tenuity of these muscles is astonishing. They are microscopic hairs; must be magnified to be visible; yet are they real effective muscles; and not only such, but the grandest and most precious of our faculties, sight and hearing, depend upon their health and action.

V. The muscles act in the limbs with what is called a mechanical disadvantage. The muscle at the shoulder, by which the arm is raised, is fixed nearly in the same manner, as the load is fixed upon a steelyard, within a few decimals, we will say, of an inch, from the centre upon which the steelyard turns. In this situation, we find that a very heavy draught is no more than sufficient to countervail the force of a small lead plummet, placed upon the long arm of the steelyard, at the distance of perhaps fifteen or twenty inches from the centre, and on the other side of it. And this is the disadvantage, which is meant. And an absolute disadvantage, no doubt, it would be, if the object were to spare the force of muscular contraction. But observe how conducive is this constitution to animal conveniency. Mechanism has always in view one or other of these two purposes; either to move a great weight slowly, and through a small space; or to move a light weight rapidly, through a considerable sweep. For the former of these purposes, a different spe-

* Phil. Trans. part I. 1800. p. 8.

cies of lever, and a different collocation of the muscles, might be better than the present: but for the second, the present structure is the true one. Now, so it happens, that the second, and not the first, is that which the occasions of animal life principally call for. In what concerns the human body, it is of much more consequence to any man to be able to carry his hand to his head with due expedition, than it would be to have the power of raising from the ground a heavier load (of two or three more hundred weight, we will suppose,) than he can lift at present. This last is a faculty, which, upon some extraordinary occasions, he may desire to possess; but the other is what he wants and uses every hour or minute. In like manner, a husbandman or a gardener will do more execution, by being able to carry his scythe, his rake or his flail, with a sufficient despatch through a sufficient space, than if, with greater strength, his motions were proportionably more confined and slow. It is the same with a mechanic in the use of his tools. It is the same also with other animals in the use of their limbs. In general, the vivacity of their motions would be ill exchanged for greater force under a clumsier structure.

We have offered our observations upon the structure of muscles in general; we have also noticed certain species of muscles; but there are also *single* muscles, which bear marks of mechanical contrivance, appropriate as well as particular. Out of many instances of this kind we select the following:

I. Of muscular actions, even of those which are well understood, some of the most curious are incapable of popular explanation; at least without the aid of plates and figures. This is in a great measure the case, with a very familiar, but, at the same time, a very complicated

motion, that of the lower jaw; and with the muscular structure by which it is produced. One of the muscles concerned, may, however, be described in such a manner, as to be, I think, sufficiently comprehended for our present purpose. The problem is to pull the lower jaw *down*. The obvious method should seem to be, to place a straight muscle, viz. to fix a string from the chin to the breast, the contraction of which would open the mouth, and produce the motion required at once. But it is evident that the form and liberty of the neck forbid a muscle being laid in such a position; and that, consistently with the preservation of this form, the motion which we want, must be effectuated, by some muscular mechanism disposed further back in the jaw. The mechanism adopted is as follows. A certain muscle called the *digastric* rises on the side of the face, considerably *above* the insertion of the lower jaw; and comes down, being converted in its progress into a round tendon. Now it is evident, that the tendon, whilst it pursues a direction *descending* towards the jaw, must, by its contraction, pull the jaw up, instead of down. What then was to be done? This, we find, is done. The descending tendon, when it is got low enough, is passed through a loop, or ring, or pulley, in the os-hyoides, and then made to ascend; and, having thus changed its line of direction, is inserted into the inner part of the chin: by which device, viz. the turn at the loop, the action of the muscle (which in all muscles is contraction) that before would have pulled the jaw up, now as necessarily draws it down. "The mouth," saith Heister, "is opened by means of this trochlea in a most wonderful and elegant manner."

II. What contrivance can be more mechanical than the following, viz. a slit in one tendon to let another ten-

don pass through it? This structure is found in the tendons which move the toes and fingers. The long tendon, as it is called, in the foot, which bends the first joint of the toe, passes *through* the short tendon which bends the second joint; which course allows to the sinew more liberty and a more commodious action than it would otherwise have been capable of exerting*. There is nothing, I believe, in a silk or cotton-mill; in the belts, or straps, or ropes, by which motion is communicated from one part of the machine to another, that is more artificial, or more evidently so, than this *perforation*.

III. The next circumstance which I shall mention, under this head of muscular arrangement, is so decisive a mark of intention, that it always appeared to me, to supersede, in some measure, the necessity of seeking for any other observation upon the subject: and that circumstance is, the tendons, which pass from the leg to the foot being bound down by a ligament at the ancle. The foot is placed at a considerable angle with the leg. It is manifest, therefore, that flexible strings, passing along the interior of the angle, if left to themselves, would, when stretched, start from it. The obvious preventative is to tie them down. And this is done in fact. Across the instep, or rather just above it, the anatomist finds a strong ligament; *under* which the tendons pass to the foot. The effect of the ligament as a bandage, can be made evident to the senses; for if it be cut, the tendons start up. The simplicity, yet the clearness of this contrivance, its exact resemblance to established resources of art, place it amongst the most indubitable manifestations of design with which we are acquainted.

There is also a further use to be made of the present

* Ches. Anat. p. 93, 119.

example, and that is, as it precisely contradicts the opinion, that the parts of animals may have been all formed by what is called appetency, i. e. endeavour, perpetuated, and imperceptibly working its effect, through an incalculable series of generations. We have here no endeavour, but the reverse of it; a constant renitency and reluctance. The endeavour is all the other way. The pressure of the ligament constrains the tendons; the tendons re-act upon the pressure of the ligament. It is impossible that the ligament should ever have been generated by the exercise of the tendon, or in the course of that exercise, forasmuch as the force of the tendon perpendicularly resists the fibre which confines it and is constantly endeavouring, not to form, but to rupture and displace, the threads, of which the ligament is composed.

Keill has reckoned up, in the human body, four hundred and forty-six muscles, dissectible and describable; and hath assigned an use to every one of the number. This cannot be all imagination.

Bishop Wilkins hath observed from Galen that there are, at least, ten several qualifications to be attended to in each particular muscle, viz. its proper figure, its just magnitude, its fulcrum, its point of action supposing the figure to be fixed, its collocation with respect to its two ends, the upper and the lower, the place, the position of the whole muscle, the introduction into it of nerves, arteries, veins. How are things, including so many adjustments, to be made; or when made, how are they to be put together, without intelligence?

I have sometimes wondered, why we are not struck with mechanism in animal bodies, as readily and as strongly as we are struck with it, at first sight, in a watch or a mill. One reason of the difference may be that animal bodies are, in a great measure, made up of soft, flabby, substances, such as muscles and membranes; whereas we have been accustomed to trace mechanism in sharp lines, in the configuration of hard materials, in the moulding, chiseling, and filing into shapes, such articles as metals or wood. There is something, therefore, of habit in the case: but it is sufficiently evident, that there can be no proper reason for any distinction of the sort. Mechanism may be displayed in the one kind of substance, as well as in the other.

Although the few instances we have selected, even as they stand in our description, are nothing short, perhaps, of logical proofs of design, yet it must not be forgotten, that, in every part of anatomy, description is a poor substitute for inspection. It was well said by an able anatomist,* and said in reference to the very part of the subject which we have been treating of, "Imperfecta hæc musculorum descriptio, non minus arida est legentibus, quam inspectantibus fuerit jucunda eorundum preparatio. Elegantissima enim mechanices artificia, creberrime in illis obvia verbis nonnisi obscure exprimuntur; carnium autem ductu, tendinum colore, insertionum proportione, et trochlearium distributione, oculis exposita, omnem superant admirationem."

* Sterno in Blas. Anat. Animal. p. 2. c. 4.

CHAPTER X.

OF THE VESSELS OF ANIMAL BODIES.

THE circulation of the *blood*, through the bodies of men and qradrupeds, and the apparatus by which it is carried on, compose a system, and testify a contrivance, perhaps the best understood of any part of the animal frame. The lymphatic vessels, or the nervous system, may be more subtile and intricate; nay it is possible that in their structure they may be even more artificial than the sanguiferous; but we do not know so much about them.

The utility of the circulation of the blood, I assume as an acknowledged point. One grand purpose is plainly answered by it; the distributing to every part, every extremity, every nook and corner, of the body, the nourishment which is received into it by one aperture. What enters at the mouth finds its way to the fingers' end. A more difficult mechanical problem could hardly I think be proposed, than to discover a method of constantly repairing the waste, and of supplying an accession of substance to every part of a complicated machine at the same time.

This system presents itself under two views: first, the disposition of the blood-vessels, i. e. the laying of the pipes; and, secondly, the construction of the engine at the centre, viz. the heart, for driving the blood through them.

I. The disposition of the blood-vessels, as far as regards the supply of the body, is like that of the water pipes in a city, viz. large and main trunks branching off by smaller pipes (and these again by still narrower

tubes) in every direction, and towards every part, in which the fluid, which they convey, can be wanted. So far the water pipes, which serve a town, may represent the vessels, which carry the blood from the heart. But there is another thing necessary to the blood, which is not wanted for the water; and that is, the carrying of it back again to its source. For this office a reversed system of vessels is prepared, which uniting at their extremities with the extremities of the first system, collects the divided and subdivided streamlets, first by capillary ramifications into larger branches, secondly by these branches into trunks; and thus returns the blood (almost exactly inverting the order in which it went out) to the fountain from whence its motion proceeded. All which is evident mechanism.

The body, therefore, contains two systems of blood-vessels, arteries and veins. Between the constitution of the systems there are also two differences, suited to the functions which the systems have to execute. The blood, in going out, passing always from wider into narrower tubes; and, in coming back, from narrower into wider; it is evident, that the impulse and pressure upon the sides of the blood-vesels, will be much greater in one case than the other. Accordingly, the arteries which carry out the blood, are formed with much tougher and stronger coats, than the veins which bring it back. That is one difference: the other is still more artificial, or, if I may so speak, indicates, still more clearly, the care and anxiety of the artificer. Forasmuch as in the arteries, by reason of the greater force with which the blood is urged along them, a wound or rupture would be more dangerous, than in the veins; these vessels are defended from injury, not only by

their texure, but by their situation; and by every advantage of situation which can be given to them. They are buried in sinuses, or they creep along grooves, made for them, in the bones; for instance, the under edge of the ribs is sloped and furrowed solely for the passage of these vessels. Sometimes they proceed in channels, protected by stout parapets on each side: which last description is remarkable in the bones of the fingers, these being hollowed out, on the under side, like a scoop, and with such a concavity that the finger may be cut across to the bone without hurting the artery which runs along it. At other times, the arteries pass in canals wrought in the substance, and in the very middle of the substance, of the bone: this takes place in the lower jaw; and is found where there would, otherwise, be danger of compression by sudden curvature. All this care is wonderful, yet not more than what the importance of the case required. To those, who venture their lives in a ship, it has been often said, that there is only an inch board between them and death; but in the body itself, especially in the arterial system, there is, in many parts, only a membrane, a skin, a thread. For which reason this system lies deep under the integuments: whereas the veins, in which the mischief that ensues from injuring the coats is much less, lie in general above the arteries; come nearer to the surface; are more exposed.

It may be further observed concerning the two systems taken together, that, though the arterial, with its trunk, and branches and small twigs, may be imagined to issue or proceed, in other words to *grow* from the heart, like a plant from its root, or the fibres of a leaf from its foot-stalk (which, however, were it so, would be only to resolve one mechanism into another,) yet the venal, the returning system, can never be formed in this manner.

The arteries might go on shooting out from their extremeties, i. e. lengthening and subdividing indefinitely; but an inverted system, continually uniting its streams, instead of dividing, and thus carrying back what the other system carried out, could not be referred to the same process.

II. The next thing to be considered is the engine which works this machinery, viz. the *heart*. For our purpose it is unnecessary to ascertain the principle upon which the heart acts. Whether it be irritation excited by the contact of the blood, by the influx of the nervous fluid, or whatever else be the cause of its motion, it is something, which is capable of producing, in a living muscular fibre, reciprocal contraction and relaxation. This is the power we have to work with: and the inquiry is, how this power is applied in the instance before us. There is provided in the central part of the body, a hollow muscle, invested with spiral fibres, running in both directions; the layers intersecting one another; in some animals, however, appearing to be semi-circular rather than spiral. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain: by the relaxation of the same fibres, the cavities are in their turn dilated; and, of course, prepared to admit every fluid which may be poured into them. Into these cavities are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back. This is a general account of the apparatus: and the simplest idea of its action is, that, by each contraction, a portion of blood is forced as by a syringe into the arteries; and, at each dilation, an equal portion is received from the veins. This produces, at each pulse, a motion and change in the mass of blood, to the amount of what

the cavity contains, which, in a full grown human heart, I understand, is about an ounce, or two table-spoons full. How quickly these changes succeed one another, and by this succession, how sufficient they are to support a stream or circulation throughout the system, may be understood by the following computation, abridged from Keill's Anatomy, p. 117. ed. 3. "Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour; from which it follows, that there passes through the heart, every hour, four thousand ounces, or three hundred and fifty pounds, of blood. Now the whole mass of blood is said to be about twenty-five pounds, so that a quantity of blood equal to the whole mass of blood passes through the heart fourteen times in one hour; which is about once every four minutes." Consider what an affair this is, when we come to very large animals. The aorta of a whale is larger in the bore than the main pipe of the water works at London Bridge; and the water roaring in its passage through that pipe, is inferior, in impetus and velocity, to the blood gushing from the whale's heart. Hear Dr. Hunter's account of the dissection of a whale. "The aorta measured a foot diameter. Ten or fifteen gallons of blood is thrown out of the heart at a stroke, with an immense velocity, through a tube of a foot diameter. The whole idea fills the mind with wonder.*"

The account which we have here stated, of the injection of blood into the arteries by the contraction, and of the corresponding reception of it from the veins by the dilation, of the cavities of the heart, and of the circulation being thereby maintained through the blood-vessels of the body, is true, but imperfect. The heart performs this office, but it is in conjunction with another of equal curiosity and importance. It was necessary that the blood

*Dr. Hunter's account of the dissection of a whale. *Phil. Trans.*

should be successively brought into contact, or contiguity, or proximity with the *air*. I do not know that the chymical reason, upon which this necessity is founded, has been yet sufficiently explored. It seems to be made appear, that the atmosphere which we breathe is a mixture of two kinds of air; one pure and vital, the other, for the purpose of life, effete, foul, and noxious: that when we have drawn in our breath, the blood in the lungs imbibes from the air, thus brought into contiguity with it, a portion of its pure ingredient; and, at the same time, gives out the effete or corrupt air which it contained, and which is carried away, along with the halitus, every time we respire. At least, by comparing the air which is breathed from the lungs, with the air before it enters the lungs, it is found to have lost some of its pure part, and to have brought away with it an addition of its impure part. Whether these experiments satisfy the question, as to the need which the blood stands in, of being visited by continual accesses of air, is not for us to inquire into; nor material to our argument: it is sufficient to know, that, in the constitution of most animals such a necessity exists, and that the air, by some means or other, *must* be introduced into a near communication with the blood. The lungs of animals are constructed for this purpose. They consist of blood-vessels and air-vessels lying close to each other; and wherever there is a branch of the trachea or windpipe, there is a branch accompanying it of the vein and artery, and the air-vessel is always in the middle between the blood-vessels.* The internal surface of these vessels, upon which the application of the air to the blood depends, would, if collected and expanded, be, in a man, equal to a superfices of fifteen feet square. Now in order to give the blood in its course, the benefit of this

* Keill's Anat. p. 121.

organization (and this is the part of the subject with which we are chiefly concerned,) the following operation takes place. As soon as the blood is received by the heart from the veins of the body, and *before* that it is sent out again into its arteries, it is carried, by the force of the contraction of the heart, and by means of a separate and supplementary artery, to the lungs, and made to enter the vessels of the lungs; from which, after it has undergone the action, whatever it be, of that viscus, it is brought back by a large vein once more to the heart, in order, when thus concocted and prepared, to be from thence distributed anew into the system. This assigns to the heart a double office. The pulmonary circulation is a system within a system; and one action of the heart is the origin of both.

For this complicated function, four cavities become necessary; and four are accordingly provided: two, called ventricles, which *send out* the blood, viz. one into the lungs, in the first instance; the other into the mass, after it has returned from the lungs: two others also, called auricles, which *receive* the blood from the veins; viz. one, as it comes immediately from the body; the other, as the same blood comes a second time after its circulation through the lungs. So that there are two receiving cavities, and two forcing cavities. The structure of the heart has reference to the lungs, for without the lungs one of each would have been sufficient. The translation of the blood in the heart itself is after this manner. The receiving cavities respectively communicate with the forcing cavities, and, by their contraction, unload the received blood into them. The forcing cavities, when it is their turn to contract, compel the same blood into the mouths of the arteries.

The account here given will not convey to a reader ignorant of anatomy, any thing like an accurate notion of

the form, action, or use of the parts (nor can any short and popular account do this,) but it is abundantly sufficient to testify contrivance; and, although imperfect, being true as far as it goes, may be relied upon for the only purpose for which we offer it, the purpose of this conclusion.

"The wisdom of the Creator;" saith Hamburgher, "is in nothing seen more gloriously than in the heart." And how well doth it execute its office! An anatomist, who understood the structure of the heart, might say beforehand that it would play: but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement, or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length o time, without disorder, and without weariness.

But further; from the account, which has been given of the mechanism of the heart, it is evident that it must require the interposition of *valves*; that the success indeed of its action must depend upon these, for when any one of its cavities contracts, the necessary tendency of the force will be to drive the inclosed blood, not only into the mouth of the artery where it ought to go, but also back again into the mouth of the vein from which it flowed. In like manner, when by the relaxation of the fibres the same cavity is dilated, the blood would not only run into it from the vein, which was the course intended, but back from the artery, through which it ought to be moving forward. The way of preventing a reflux of the fluid, in both these cases, is to fix valves; which, like flood-gates,

may open a way to the stream in one direction, and shut up the passage against it in another. The heart, constituted as it is, can no more work without valves than a pump can. When the piston descends in a pump, if it were not for the stoppage by the valve beneath, the motion would only thrust down the water, which it had before drawn up. A similar consequence would frustrate the action of the heart. Valves, therefore, properly disposed, i. e. properly with respect to the course of the blood which it is necessary to promote, are essential to the contrivance. *And valves so disposed are, accordingly, provided.* A valve is placed in the communication between each auricle and its ventricle, lest when the ventricle contracts, part of the blood should get back again into the auricle, instead of the whole entering, as it ought to do, the mouth of the artery. A valve is also fixed at the mouth of each of the great arteries which take the blood from the heart: leaving the passage free, so long as the blood holds its proper course forward; closing it, whenever the blood, in consequence of the relaxation of the ventricle, would attempt to flow back. There is some variety in the construction of these valves, though all the valves of the body act nearly upon the same principle, and are destined to the same use. In general they consist of a thin membrane, lying close to the side of the vessel, and consequently allowing an open passage whilst the stream runs one way, but thrust out from the side by the fluid getting behind it, and opposing the passage of the blood, when it would flow the other way. Where more than one membrane is employed, the different membranes only compose one valve. Their joint action fulfils the office of valve: for instance; over the entrance of the right auricle of the heart into the right ventricle, three of these skins or membranes are fixed; of a triangular fi-

gure; the bases of the triangles fastened to the flesh; the sides and summits loose; but, though loose, connected by threads of a determinate length with certain small fleshy prominences adjoining. The effect of this construction is, that, when the ventricle contracts, the blood endeavouring to escape in all directions, and amongst other directions pressing upwards, gets *between* these membranes and the sides of the passage; and thereby forces them up into such a position, as that, together, they constitute, when raised, a hollow cone (the strings before spoken of, hindering them from proceeding or separating further;) which cone, entirely occupying the passage, prevents the return of the blood into the auricle. A shorter account of the matter may be this: So long as the blood proceeds in its proper course, the membranes which compose the valve are pressed close to the side of the vessel, and occasion no impediment to the circulation; when the blood would regurgitate, they are raised from the side of the vessel, and meeting in the middle of its cavity, shut up the channel. Can any one doubt of contrivance here; or is it possible to shut our eyes against the proof of it?

This valve also, is not more curious in its structure, than it is important in its office. Upon the play of the valve, even upon the proportioned length of the strings or fibres which check the ascent of the membranes, depends, as it should seem, nothing less than the life itself of the animal. We may here likewise repeat, what we before observed concerning some ligaments of the body, that they could not be formed by any action of the parts themselves. There are cases, in which, although good uses appear to arise from the shape or configuration of a part, yet that shape and configuration itself may seem to be

produced by the action of the part, or the action or pressure of adjoining parts. Thus the bend, and the internal smooth concavity of the ribs, may be attributed to the equal pressure of the soft bowels; the particular shape of some bones and joints, to the traction of the annexed muscles, or to the position of contiguous muscles. But valves could not be so formed. Action and pressure are all against them. The blood, in its proper course, has no tendency to produce such things; and, in its improper or reflected current, has a tendency to prevent their production. Whilst we see therefore the use and necessity of this machinery, we can look to no other account of its origin or formation than the intending mind of a Creator. Nor can we without admiration reflect, that such thin membranes, such weak and tender instruments, as these valves are, should be able to hold out for seventy or eighty years.

Here also we cannot consider but with gratitude, how happy it is that our vital motions are *involuntary*. We should have enough to do, if we had to keep our hearts beating, and our stomachs at work. Did these things depend, we will not say upon our effort, but upon our bidding, our care, or our attention, they would leave us leisure for nothing else. We must have been continually upon the watch, and continually in fear: nor would this constitution have allowed of sleep.

It might perhaps be expected, that an organ so precious, of such central and primary importance, as the heart is, should be defended by *a case*. The fact is, that a membranous purse or bag, made of strong tough materials, is provided for it; holding the heart within its cavity; sitting loosely and easily about it; guarding its substance, without confining its motion; and containing likewise a spoonful or two of water, just sufficient to keep

the surface of the heart in a state of suppleness and moisture. How should such a loose covering be generated by the action of the heart? Does not the inclosing of it in a sack, answering no other purpose but that inclosure, show the care that has been taken of its preservation?

One use of the circulation of the blood (probably amongst other uses) is to distribute nourishment to the different parts of the body. How minute and multiplied the ramifications of the blood-vessels, for that purpose, are; and how thickly spread, over at least the superfices of the body, is proved by the single observation, that we cannot prick the point of a pin into the flesh, without drawing blood, i. e. without finding a blood-vessel. Nor, externally, is their diffusion less universal. Blood-vessels run along the surface of membranes, pervade the substance of muscles, penetrate the bones. Even into every tooth, we trace, through a small hole in the root, an artery to feed the bone, as well as a vein to bring back the spare blood from it; both which, with the addition of an accompanying nerve, form a thread only a little thicker than a horse-hair.

Wherefore, when the nourishment taken in at the mouth, has once reached, and mixed itself with, the blood, every part of the body is in the way of being supplied with it. And this introduces another grand topic, namely, the manner in which the aliment gets into the *blood*; which is a subject distinct from the preceding, and brings us to the consideration of another entire system of vessels.

II. For this necessary part of the animal economy an apparatus is provided, in a great measure, capable of being, what anatomists call, demonstrated, that is, shown in the dead body; and a line or course of conveyance, which we can pursue by our examinations.

First, The food descends by wide passages into the intestines, undergoing two great preparations on its way, one, in the mouth by mastication and moisture, (can it be doubted with what design the teeth were placed in the road to the stomach, or that there was choice in fixing them in this situation?) The other by digestion in the stomach itself. Of this last surprising dissolution I say nothing; because it is chymistry, and I am endeavouring to display mechanism. The figure and position of the stomach (I speak all along with a reference to the human organ) are calculated for detaining the food long enough for the action of its digestive juice. It has the shape of the pouch of a bag-pipe; lies across the body; and the pylorus, or passage by which the food leaves it, is somewhat higher, in the body, than the cardia or orifice by which it enters; so that it is by the contraction of the muscular coat of the stomach, that the contents, after having undergone the application of the gastric menstruum, are gradually pressed out. In dogs and cats, this action of the coats of the stomach has been displayed to the eye. It is a slow and gentle undulation, propagated from one orifice of the stomach to the other. For the same reason that I omitted, for the present, offering any observation upon the digestive fluid, I shall say nothing concerning the bile or the pancreatic juice, further than to observe upon the mechanism, viz. that from the glands in which those secretions are elaborated, pipes are laid into the first of these intestines, through which pipes the product of each gland flows into that bowel, and is there mixed with the aliment, as soon almost as it passes the stomach: adding also as a remark, how grievously this same bile offends the stomach itself, yet cherishes the vessel that lies next to it.

Secondly, We have now the aliment in the intestines, converted into pulp, and, though lately consisting of per-

haps ten different viands, reduced to nearly an uniform substance, and to a state fitted for yielding its essence, which is called chyle, but which is milk, or more nearly resembling milk than any other liquor with which it can be compared. For the straining off of this fluid from the digested aliment in the course of its long progress through the body, myriads of capillary tubes, i. e. pipes as small as hairs, open their orifices into the cavity of every part of the intestines. These tubes, which are so fine and slender as not to be visible unless when distended with chyle, soon unite into larger branches. The pipes, formed by this union, terminate in glands, from which other pipes of a still larger diameter arising, carry the chyle, from all parts, into a common reservoir or *receptacle*. This receptacle is a bag, large enough to hold about two table spoons full; and from this vessel a duct or main pipe proceeds, climbing up the back part of the chest, and then creeping along the gullet till it reach the neck. Here it meets the river. Here it discharges itself into a large vein, which soon conveys the chyle, now flowing along with the old blood, to the heart. This whole route can be exhibited to the eye. Nothing is left to be supplied by imagination or conjecture. Now, beside the subserviency of this whole structure to a manifest and necessary purpose, we may remark two or three separate particulars in it, which show, not only the contrivance, but the perfection of it. We may remark, first, the length of the intestines, which, in the human subject, is six times that of the body. Simply for a passage, these voluminous bowels, this prolixity of gut, seems in no wise necessary; but, in order to allow time and space for the successive extraction of the chyle from the digested aliment, namely, that the chyle, which escapes the lacteals of one part of the guts,

may be taken up by those of some other part, the length of the canal is of evident use and conduciveness. Secondly, We must also remark their peristaltic motion; which is made up of contractions, following one another like waves upon the surface of a fluid; and not unlike what we observe in the body of an earthworm crawling along the ground; and which is effected by the joint action of longitudinal and of spiral, or rather perhaps of a great number of separate semi-circular fibres. This curious action pushes forward the grosser part of the aliment, at the same time that the more subtile parts, which we call chyle, are, by a series of gentle compressions, squeezed into the narrow orifices of the lacteal veins. Thirdly, It was necessary that these tubes, which we denominate lacteals, or their mouths at least, should be made as narrow as possible, in order to deny admission into the blood to any particle, which is of size enough to make a lodgement afterwards in the small arteries, and thereby to obstruct the circulation: and it was also necessary that this extreme tenuity should be compensated by multitude; for a large quantity of chyle (in ordinary constitutions, not less, it has been computed, than two or three quarts in a day) is, by some means or other, to be passed through them. Accordingly, we find the number of the lacteals exceeding all powers of computation; and their pipes so fine and slender, as not to be visible, unless filled, to the naked eye; and their orifices, which open into the intestines, so small, as not to be discernible even by the best microscope. Fourthly, The main pipe which carries the chyle from the reservoir to the blood, viz. the thoracic duct, being fixed in an almost upright position, and wanting that advantage of propulsion which the arteries possess, is furnished with a succession of valves to check the ascending fluid, when once it has passed them, from fall-

ing back. These valves look upwards, so as to leave the ascent free, but to prevent the return of the chyle, if for want of sufficient force to push it on, its weight should at any time cause it to descend. Fifthly, The chyle enters the blood in an odd place, but perhaps the most commodious place possible, viz. at a large vein in the neck, so situated with respect to the circulation, as speedily to bring the mixture to the heart. And this seems to be a circumstance of great moment; for had the chyle entered the blood at any artery, or at a distant vein, the fluid, composed of the old and the new materials, must have performed a considerable part of the circulation, before it received that churning in the lungs, which is, probably, necessary for the intimate and perfect union of the old blood with the recent chyle. Who could have dreamt of a communication between the cavity of the intestines and the left great vein of the *neck*? Who could have suspected that this communication should be the medium through which all nourishment is derived to the body; or this the place, where, by a side inlet, the important junction is formed between the blood and the material which feeds it?

We postponed the consideration of *digestion*, lest it should interrupt us in tracing the course of the food to the blood; but, in treating of the alimentary system, so principal a part of the process cannot be omitted.

Of the gastric juice, the immediate agent by which that change which food undergoes in our stomachs is effected, we shall take our account, from the numerous, careful, and varied experiments, of the Abbe Spallanzani.

1. It is not a simple diluent, but a real solvent. A quarter of an ounce of beef had scarce touched the stomach of a crow, when the solution began.

2. It has not the nature of saliva; it has not the na-

ture of bile; but is distinct from both. By experiments out of the body it appears, that neither of these secretions act upon alimentary substances, in the same manner as the gastric juice acts.

3. Digestion is not *putrefaction*; for it resists putrefaction most pertinaciously; nay, not only checks its further progress, but restores putrid subtances.

4. It is not a *fermentative* process; for the solution begins at the surface, and proceeds towards the centre, contrary to the order in which fermentation acts and spreads.

5. It is not the *digestion of heat*; for the cold maw of a cod or sturgeon will dissolve the shells of crabs and lobsters, harder than the sides of the stomach which contains them.

In a word, animal digestion carries about it the marks of being a power and a process, completely *sui generis*; distinct from every other; at least from every chymical process with which we are acquainted. And the most wonderful thing about it is its appropriation; its subserviency to the particular economy of each animal. The gastric juice of an owl, falcon, or kite, will not touch grain: no, not even to finish the macerated and half digested pulse, which is left in the crops of the sparrows that the bird devours. In poultry, the trituration of the gizzard, and the gastric juice, conspire in the work of digestion. The gastric juice will not dissolve the grain whilst it is whole. Grains of barley inclosed in tubes or spherules, are not affected by it. But if the same grain be by any means broken or ground, the gastric juice immediately lays hold of it. Here then is wanted, and here we find, a combination of mechanism and chymistry. For the preparatory grinding, the gizzard lends its mill. And, as all mill work should be strong, its structure is so, beyond that

of any other muscle belonging to the animal. The internal coat also, or lining of the gizzard, is, for the same purpose, hard and cartilaginous. But, forasmuch as this is not the sort of animal substance suited for the reception of glands, or for secretion, the gastric juice, in this family, is not supplied, as in membranous stomachs, by the stomach itself, but by the gullet, in which the feeding glands are placed, and from which it trickles down into the stomach.

In sheep, the gastric fluid has no effect in digesting plants *unless they have been previously masticated.* It only produces a slight maceration; nearly such as common water would produce, in a degree of heat somewhat exceeding the medium temperature of the atmosphere. But, provided that the plant has been reduced to pieces by chewing, the gastric juice then proceeds with it, first by softening its substance; next by destroying its natural consistency; and, lastly, by dissolving it so completely, as not even to spare the toughest and most stringy parts, such as the nerves of the leaves.

So far our accurate and indefatigable Abbe. Dr. Stevens, of Edinburgh, in 1777, found by experiments tried with perforated balls, that the gastric juice of the sheep and the ox speedily dissolved vegetables, but made no impression upon beef, mutton, and other animal bodies. Dr. Hunter discovered a property of this fluid, of a most curious kind; viz. that, in the stomachs of animals which feed upon flesh, irresistably as this fluid acts upon animal substances, it is only upon the *dead* substance, that it operates at all. The *living* fibre suffers no injury from lying in contact with it. Worms and insects are found alive in the stomachs of such animals. The coats of the human stomach in a healthy state, are insensible to its presence; yet, in cases of sudden death, (wherein the gastric juice,

not having been weakened by disease, retains its activity,) it has been known to eat a hole through the bowel which contains it.* How nice is this discrimination of action, yet how necessary?

But to return to our hydraulics.

III. The gall bladder is a very remarkable contrivance. It is the reservoir of a canal. It does not form the channel itself, i. e. the direct communication between the liver and the intestine, which is by another passage, viz. the ductus hepaticus, continued under the name of the ductus communis; but it lies adjacent to this channel, joining to it by a duct of its own, the ductus cysticus; by which structure it is enabled, as occasions may require, to add its contents to, and increase, the flow of bile into the duodenum. And the position of the gall bladder is such as to apply this structure to the best advantage. In its natural situation it touches the exterior surface of the stomach, and consequently is compressed by the distension of that vessel; the effect of which compression is, to force out from the bag, and send into the duodenum, an extraordinary quantity of bile, to meet the extraordinary demand which the repletion of the stomach by food is about to occasion.† Cheselden describes‡ the gall bladder as seated against the duodenum, and thereby liable to have its fluid pressed out, by the passage of the aliment through that cavity; which likewise will have the effect of causing it to be received into the intestine, at a right time, and in a due proportion.

There may be other purposes answered by this contrivance; and it is probable, that there are. The contents of the gall bladder are not exactly of the same kind as what passes from the liver through the direct passage.§ It

* Phil. Trans. vol. lxii. p. 447. † Keill's Anat. p. 64.

‡ Anat. p. 164. § Keill's from Malpighius, p. 62.

is possible that the gall may be changed, and for some purposes, meliorated by keeping.

The entrance of the gall duct into the duodenum furnishes another observation. Whenever either smaller tubes are inserted into larger tubes, or tubes into vessels and cavities, such receiving tubes, vessels, or cavities, being subject to muscular constriction, we always find a contrivance to prevent *regurgitation*. In some cases, valves are used; in other cases, amongst which is that now before us, a different expedient is resorted to: which may be thus described. The gall duct enters the duodenum obliquely: after it has pierced the first coat, it runs near two fingers breadth *between* the coats, before it opens into the cavity of the intestine.† The same contrivance is used in another part, where there is exactly the same occasion for it, viz. in the insertion of the ureters into the bladder. These enter the bladder near its neck, running obliquely for the space of an inch between its coats.‡ It is, in both cases, sufficiently evident, that this structure has a necessary mechanical tendency to resist regurgitation; for whatever force acts in such a direction as to urge the fluid back into the orifices of the tubes, must, at the same time, stretch the coats of the vessels, and, thereby compress that part of the tube, which is included between them.

IV. Amongst the *vessels* of the human body, the pipe which conveys the saliva from the place where it is made, to the place where it is wanted, deserves to be reckoned amongst the most intelligible pieces of mechanism with which we are acquainted. The saliva, we all know, is used in the mouth; but much of it is manufactured on the outside of the cheek, by the parotid gland, which lies between the ear and the angle of the lower jaw. In order

† Keill's Anat. p. 62. ‡ Ches. Anat. p. 260.

to carry the secreted juice to its destination, there is laid from the gland on the outside, a pipe, about the thickness of a wheat straw, and about three fingers breadth in length; which, after riding over the masseter muscle, bores for itself a hole through the very middle of the cheek; enters by that hole, which is a complete perforation of the baccinator muscle, into the mouth; and there discharges its fluid very copiously.

V. Another exquisite structure, differing indeed from the four preceding instances, in that it does not relate to the conveyance of fluids, but still belonging, like these, to the class of pipes or conduits of the body, is seen in the *larynx*. We all know, that there go down the throat two pipes, one leading to the stomach, the other to the lungs; the one being the passage for the food, the other for the breath and voice: we know also that both the passages open into the bottom of the mouth; the gullet, necessarily, for the conveyance of the food; and the windpipe, for the speech and the modulation of sound, not much less so: therefore, the difficulty was, the passages being so contiguous, to prevent the food, especially the liquids, which we swallow into the stomach, from entering the wind-pipe, i. e. the road to the lungs; the consequence of which error, when it does happen, is perceived by the convulsive throes that are instantly produced. This business, which is very nice, is managed in this manner. The gullet (the passage for food) opens into the mouth like the cone or upper part of a funnel, the capacity of which forms indeed the bottom of the mouth. Into the side of this funnel, at the part which lies the lowest, enters the windpipe, by a chink or slit, with a lid or flap, like a little tongue, accurately fitted to the orifice. The solids or liquids which we swallow, pass over this lid or flap, as they descend by the funnel into the gullet. Both the weight of the food,

and the action of the muscles concerned in swallowing, contribute to keep the lid close down upon the aperture, whilst any thing is passing; whereas, by means of its natural cartilagenous spring, it raises itself a little, as soon as the food is passed, thereby allowing a free inlet and outlet for the respiration of air by the lungs. And we may here remark the almost complete success of the expedient, viz. how seldom it fails of its purpose, compared with the number of instances in which it fulfils it. Reflect, how frequently we swallow, how constantly we breathe. In a city feast, for example, what deglutition, what anhelation! yet does this little cartilage, the epiglottis, so effectually interpose its office, so securely guard the entrance of the windpipe, that, whilst morsel after morsel, draught after draught, are coursing one another over it, an accident of a crumb or a drop slipping into this passage, (which nevertheless must be opened for the breath every second time,) excites, in the whole company, not only alarm by its danger, but surprise by its novelty. Not two guests are choked in a century.

There is no room for pretending, that the action of the parts may have gradually formed the epiglottis: I do not mean in the same individual, but in a succession of generations. Not only the action of the parts has no such tendency, but the animal could not live, nor consequently the parts act, either without it, or with it in a half formed state. The species was not to wait for the gradual formation or expansion of a part, which was, from the first, necessary to the life of the individual.

Not only is the larynx curious, but the whole windpipe possesses a structure, adapted to its peculiar office. It is made up, (as any one may perceive by putting his fingers to his throat)—of stout cartilaginous ringlets, placed at

small and equal distances from one another. Now this is not the case with any other of the numerous conduits of the body. The use of these cartilages is to keep the passage for the air *constantly* open; which they do mechanically. A pipe with soft membranous coats, liable to collapse and close when empty, would not have answered here; although this be the general vascular structure, and a structure which serves very well for those tubes, which are kept in a state of perpetual distension by the fluid they inclose, or which afford a passage to solid and protruding substances.

Nevertheless, (which is another particularity well worthy of notice,) these rings are not complete, that is, are not cartilaginous and stiff all round; but their hinder part, which is contiguous to the gullet, is membranous and soft, easily yielding to the distensions of that organ occasioned by the descent of solid food. The same rings are also bevelled off at the upper and lower edges, the better to close upon one another, when the trachea is compressed or shortened.

The constitution of the trachea may suggest likewise another reflection. The membrane which lines its inside, is, perhaps, the most sensible, irritable, membrane of the body. It rejects the touch of a crumb of bread, or a drop of water, with a spasm which convulses the whole frame; yet, left to itself, and its proper office, the intromission of air alone, nothing can be so quiet. It does not even make itself felt: a man does not know that he has a trachea. This capacity of perceiving with such acuteness; this impatience of offence, yet perfect rest and ease when let alone; are properties, one would have thought, not likely to reside in the same subject. It is to the junction, however, of these almost inconsistent qualities, in this as well as in some other delicate parts of the body, that we owe

our safety and our comfort; our safety to their sensibility, our comfort to their repose.

The larynx, or rather the whole windpipe taken together, (for the larynx is only the upper part of the windpipe,) besides its other uses, is also a musical instrument, that is to say, it is *mechanism* expressly adapted to the modulation of sound; for it has been found upon trial, that, by relaxing or tightening the tendinous bands at the extremity of the windpipe, and blowing in at the other end, all the cries and notes might be produced of which the living animal was capable. It can be sounded, just as a pipe or flute is sounded. Birds, says Bonnet, have, at the lower end of the windpipe, a conformation like the reed of a hautboy, for the modulation of their notes. A tuneful bird is a ventriloquist. The seat of the song is in the breast.

The use of the lungs in the system has been said to be obscure: one use however is plain, though, in some sense, external to the system, and that is, the formation, in conjunction with the larynx, of voice and speech. They are, to animal utterance, what the bellows are to the organ.

For the sake of method, we have considered animal bodies under three divisions, their bones, their muscles, and their vessels: and we have stated our observations upon these parts separately. But this is to diminish the strength of the argument. The wisdom of the Creator is seen, not in their separate but their collective action; in their mutual subserviency and dependence; in their contributing *together* to one effect, and one use. It has been said, that a man cannot lift his hand to his head without finding enough to convince him of the existence of a God.

And it is well said; for he has only to reflect, familiar as this action is, and simple as it seems to be, how many things are requisite for the performing of it; how many things which we understand, to say nothing of many more, probably, which we do not; viz. first, a long, hard, strong cylinder, in order to give to the arm its firmness and tension; but which, being rigid, and in its substance, inflexible, can only turn upon joints: secondly, therefore, joints for this purpose, one at the shoulder to raise the arm, another at the elbow to bend it; these joints continually fed with a soft mucilage to make the parts slip easily upon one another, and held together by strong braces to keep them in their position: then, thirdly, strings and wires, i. e. muscles and tendons, artificially inserted for the purpose of drawing the bones in the directions in which the joints allow them to move. Hitherto we seem to understand the mechanism pretty well; and understanding this, we possess enough for our conclusion: nevertheless we have hitherto only a machine standing still; a dead organization; an apparatus. To put the system in a state of activity (to set it at work) a further provision is necessary, viz. a communication with the brain by means of nerves. We know the existence of this communication, because we can see the communicating threads, and can trace them to the brain: its necessity we also know, because, if the thread be cut, if the communication be intercepted, the muscle becomes paralytic: but beyond this we know little; the organization being too minute and subtile for our inspection.

To what has been enumerated, as officiating in the single act of a man's raising his hand to his head, must be added, likewise, all that is necessary, and all that contributes, to the growth, nourishment, and sustentation of the limb, the repair of its waste, the preservation of its

health: such as the circulation of the blood through every part of it: its lymphatics, exhalants, absorbents; its excretions and integuments. All these share in the result; join in the effect: and how all these, or any of them come together without a designing, disposing intelligence, it is impossible to conceive.

CHAPTER XI.

OF THE ANIMAL STRUCTURE REGARDED AS A MASS.

CONTEMPLATING an animal body in its collective capacity, we cannot forget to notice, what a number of instruments are brought together, and often within how small a compass. In a Canary bird, for instance, and in the ounce of matter which composes its body (but which seems to be all employed,) we have instruments for eating, for digesting, for nourishment, for breathing, for generation, for running, for flying, for seeing, for hearing, for smelling; each appropriate; each entirely different from all the rest.

The human, or indeed the animal frame, considered as a mass or assemblage, exhibits in its composition three properties, which have long struck my mind, as indubitable evidences, not only of design, but of a great deal of attention and accuracy in prosecuting the design.

I. The first is, the exact correspondency of the two sides of the same animal; the right hand answering to the left, leg to leg, eye to eye, one side of the countenance to the other; and with a precision, to imitate which in any tolerable degree, forms one of the difficulties of statuary, and requires, on the part of the artist, a constant attention to this property of his work, distinct from every other.

It is the most difficult thing that can be to get a wig made even; yet how seldom is the *face* awry? And what care is taken that it should not be so, the anatomy of its bones demonstrates. The upper part of the face is composed of thirteen bones, six on each side, answering each to each, and the thirteenth, without a fellow, in the middle: the lower part of the face is in like manner composed of six bones, three on each side, respectively corres-

ponding, and the lower jaw in the centre. In building an arch could more be done in order to make the curve *true*? i. e. the parts equi-distant from the middle, alike in figure and position.

The exact resemblance of the *eyes*, considering how compound this organ is in its structure, how various and how delicate are the shades of colour with which its iris is tinged, how differently, as to effect upon appearance, the eye may be mounted in its socket, and how differently in different heads eyes actually are set, is a property of animal bodies much to be admired. Of ten thousand eyes, I do not know that it would be possible to match one, except with its own fellow; or to distribute them into suitable pairs by any other selection than that which obtains.

This regularity of the animal structure is rendered more remarkable by the three following considerations. First, the limbs, separately taken, have not this correlation of parts; but the contrary of it. A knife drawn down the chine cuts the human body into two parts, externally equal and alike; you cannot draw a straight line which will divide a hand, a foot, the leg, the thigh, the cheek, the eye, the ear, into two parts equal and alike. Those parts which are placed upon the middle or partition line of the body, or which traverse that line, as the nose, the tongue, the lips, may be so divided, or, more properly speaking, are double organs; but other parts cannot. This shows that the correspondency which we have been describing, does not arise by any necessity in the nature of the subject; for, if necessary, it would be universal, whereas it is observed only in the system or assemblage: it is not true of the separate parts: that is to say, it is found where it conduces to beauty or utility; it is not found, where it would subsist at the expense of both. The two wings of a bird always correspond; the two sides of

a feather frequently do not. In centipedes, millepedes, and that whole tribe of insects, no two legs on the same side are alike; yet there is the most exact parity between the legs opposite to one another.

2. The next circumstance to be remarked, is, that, whilst the cavities of the body are so configurated, as, *externally*, to exhibit the most exact correspondency of the opposite sides, the contents of these cavities have no such correspondency. A line drawn down the middle of the breast divides the thorax into two sides exactly similar; yet these two sides inclose very different contents. The heart lies on the left side; a lobe of the lungs on the right; balancing each other, neither in size nor shape. The same thing holds of the abdomen. The liver lies on the right side, without any similar viscus opposed to it on the left. The spleen indeed is situated over against the liver; but agreeing with the liver, neither in bulk nor form. There is no equipollency between these. The stomach is a vessel, both irregular in its shape, and oblique in its position. The foldings and doublings of the intestines do not present a parity of sides. Yet that symmetry which depends upon the correlation of the sides, is externally preserved throughout the whole trunk: and is the more remarkable in the lower parts of it, as the integuments are soft; and the shape, consequently, is not, as the thorax is by its ribs, reduced by natural stays. It is evident, therefore, that the external proportion does not arise from any equality in the shape or pressure of the internal contents. What is it indeed but a correction of inequalities? an adjustment, by mutual compensation of anomalous forms into a regular congeries? the effect, in a word, of artful, and, if we might be permitted so to speak, of studied collocation?

3. Similar also to this, is the third observation; that

an internal inequality in the feeding vessels is so managed, as to produce no inequality in parts which were intended to correspond. The right arm answers accurately to the left, both in size and shape; but the arterial branches, which supply the two arms, do not go off from their trunk, in a pair, in the same manner, at the same place, or at the same angle. Under which want of similitude, it is very difficult to conceive how the same quantity of blood should be pushed through each artery: yet the result is right; the two limbs, which are nourished by them, perceive no difference of supply, no effects of excess or deficiency.

Concerning the difference of manner, in which the subclavan and carotid arteries, upon the different sides of the body, separate themselves from the aorta, Chesselden seems to have thought, that the advantage which the left gain by going off at a much acuter angle than the right, is made up to the right by their going off together in one branch.* It is very possible that this may be the compensating contrivance: and, if it be so, how curious, how hydrostatical!

II. Another perfection of the animal mass is the *package*. I know nothing which is so surprising. Examine the contents of the trunk of any large animal. Take notice how soft, how tender, how intricate they are; how constantly in action, how necessary to life. Reflect upon the danger of any injury to their substance, any derangement of their position, any obstruction to their office. Observe the heart pumping at the centre, at the rate of eighty strokes in a minute: one set of pipes carrying the stream away from it, another set, bringing, in its course, the fluid back to it again: the lungs performing their elaborate office, viz. distending and contracting their many thousand

* Ches. Anat. p. 184. ed. 7.

vesicles, by a reciprocation which cannot cease for a minute: the stomach exercising its powerful chymistry: the bowels silently propelling the changed aliment; collecting from it, as it proceeds, and transmitting to the blood an incessant supply of prepared and assimilated nourishment: that blood pursuing its course: the liver, the kidneys, the pancreas, the parotid, with many other known and distinguishable glands, drawing off from it, all the while, their proper secretions. These several operations, together with others more subtile but less capable of being investigated, are going on within us, at one and the same time. Think of this; and then observe how the body itself, the case which holds this machinery, is rolled, and jolted, and tossed about, the mechanism remaining unhurt, and with very little molestation even of its nicest motions. Observe a rope dancer, a tumbler, or a monkey; the sudden inversions and contortions which the internal parts sustain by the postures into which their bodies are thrown; or rather observe the shocks, which these parts, even in ordinary subjects, sometimes receive from falls and bruises, or by abrupt jerks and twists, without sensible, or with soon recovered damage. Observe this, and then reflect how firmly every part must be secured, how carefully surrounded, how well tied down and packed together.

This property of animal bodies has never, I think, been considered under a distinct head, or so fully as it deserves. I may be allowed, therefore, in order to verify my observation concerning it, to set forth a short anatomical detail, though it oblige me to use more technical language, than I should wish to introduce into a work of this kind.

1. The *heart* (such care is taken of the centre of life) is placed between two soft lobes of the lungs; is *tied* to

the mediastinum and to the pericardium, which pericardium is not only itself an exceedingly strong membrane, but *adheres* firmly to the duplicature of the mediastinum, and, by its point, to the middle tendon of the diaphragm. The heart is also *sustained* in its place by the great blood-vessels which issue from it.*

2. The *lungs* are *tied* to the sternum by the mediastinum, before; to the vertebræ by the pleura, behind. It seems indeed to be the very use of the mediastinum (which is a membrane that goes straight through the middle of the thorax, from the breast to the back) to keep the contents of the thorax in their places; in particular to hinder one lobe of the lungs from incommoding another, or the parts of the lungs from pressing upon each other when we lie on one side.†

3. The *liver* is fastened in the body by two ligaments; the first, which is large and strong, comes from the covering of the diaphragm, and penetrates the substance of the liver; the second is the umbilical vein, which, after birth, degenerates into a ligament. The first, which is the principal, fixes the liver in its situation, whilst the body holds an erect posture; the second prevents it from pressing upon the diaphragm when we lie down; and both together sling or suspend the liver when we lie upon our backs, so that it may not compress or obstruct the ascending vena cava,‡ to which belongs the important office of returning the blood from the body to the heart.

4. The *bladder* is tied to the navel by the urachus transformed into a ligament: thus what was a passage for urine to the fœtus, becomes, after birth, a support or stay to the bladder. The peritonæum also keeps the viscera from confounding themselves with, or pressing

* Keill's Anat. p. 107. ed. 3. † Keill's Anat. p. 119. ed. 3.
‡ Ches. Anat. p. 162.

irregularly upon the bladder: for the kidneys and bladder are contained in a distinct duplicature of that membrane, being thereby partitioned off from the other contents of the abdomen.

5. The *kidneys* are lodged in a bed of fat.

6. The *pancreas* or sweetbread is strongly tied to the peritonæum, which is the great wrapping sheet, that incloses all the bowels contained in the lower belly.*

7. The *spleen* also is confined to its place by an adhesion to the peritonæum and diaphragm, and by a connexion with the omentum.† It is possible, in my opinion, that the spleen may be merely a *stuffing*, a soft cushion, to fill up a vacancy or hollow, which, unless occupied, would leave the package loose and unsteady: for supposing that it answers no other purpose than this, it must be vascular, and admit of a circulation through it, in order to be kept alive, or be a part of a living body.

8. The *omentum*, epiploon, or caul, is an apron, tucked up, or doubling upon itself, at its lowest part. The upper edge is tied to the bottom of the stomach, to the spleen, as hath already been observed, and to part of the duodenum. The reflected edge also, after forming a doubling, comes up behind the front flap, and is tied to the colon and adjoining viscera.‡

9. The septa of the brain, probably, prevent one part of that organ from pressing with too great a weight upon another part. The processes of the dura matter divide the cavity of the scull, like so many inner partition walls; and thereby, confine each hemisphere and lobe of the brain to the chamber which is assigned to it, without its being liable to rest upon, or intermix with the neighbouring parts. The great art and caution of packing

* Keill's Anat. p. 57. † Ches. Anat. p. 167.
‡ Ches. Anat. p. 149.

is to prevent one thing hurting another. This, in the head, the chest, and the abdomen, of an animal body, is, amongst other methods, provided for, by membranous partitions and wrappings, which keep the parts separate.

The above may serve as a short account of the manner in which the principal viscera are sustained in their places. But, of the provisions for this purpose, by far, in my opinion, the most curious, and where also such a provision was most wanted, is in the *guts*. It is pretty evident, that a long narrow tube (in man about five times the length of the body) laid from side to side in folds upon one another, winding in oblique and circuitous directions, composed also of a soft and yielding substance, must, without some extraordinary precaution for its safety, be continually displaced by the various, sudden, and abrupt motions of the body which contains it. I should expect, that, if not bruised or wounded by every fall, or leap, or twist, it would be entangled, or be involved with itself; or, at the least, slipped and shaken out of the order in which it is disposed, and which order is necessary to be preserved for the carrying on of the important functions, which it has to execute in the animal economy. Let us see therefore how a danger so serious, and yet so natural to the length, narrowness, and tubular form of the part, is provided against. The expedient is admirable, and it is this. The intestinal canal, throughout its whole process, is knit to the edge of a broad fat membrane, called the mesentery. It forms the margin of this mesentery, being stitched and fastened to it like the edging of a ruffle; being four times as long as the mesentery itself, it is, what a sempstress would call, "gathered on" to it. This is the nature of the connexion of the gut with the mesetery; and being thus

joined to, or rather made a part of the mesentery, it is folded and wrapped up together with it. Now the mesentery, having a considerable dimension in breadth, being in its substance withhal, both thick and suety, is capable of a close and safe folding, in comparison of what the intestinal tube would admit of, if it had remained loose. The mesentery likewise not only keeps the intestinal canal in its proper place and position under all the turns and windings of its course, but sustains the numberless small vessels, the arteries, the veins, the lympheducts, and, above all, the lacteals, which lead from or to almost every point of its coats and cavity. This membrane, which appears to be the great support and security of the alimentary apparatus, is itself strongly tied to the first three vertebræ of the loins.*

III. A third general property of animal forms is *beauty*. I do not mean relative beauty, or that of one individual above another of the same species, or of one species compared with another species; but I mean generally, the provision which is made in the body of almost every animal, to adapt its appearance to the perception of the animals with which it converses. In our own species, for example, only consider what the parts and materials are, of which the fairest body is composed; and no further observation will be necessary to show, how well these things are wrapped up so as to form a mass, which shall be capable of symmetry in its proportion, and of beauty in its aspect; how the bones are covered, the bowels concealed, the roughnesses of the muscles smoothed and softened; and how over the whole is drawn an integument which converts the disgusting materials of a dissecting-room into an object of attraction to the sight, or one, upon which it rests, at

* Keill's Anat. p. 45.

least, with ease and satisfaction. Much of this effect is to be attributed to the intervention of the cellular or adipose membrane, which lies immediately under the skin; is a kind of lining to it; is moist, soft, slippery, and compressible; every where filling up the interstices of the muscles, and forming thereby their roundness and flowing line, as well as the evenness and polish of the whole surface.

All which seems to be a strong indication of design, and of a design studiously directed to this purpose. And it being once allowed, that such a purpose existed with respect to any of the productions of nature, we may refer, with a considerable degree of probability, other particulars to the same intention; such as the tints of flowers, the plumage of birds, the furs of beasts, the bright scales of fishes, the painted wings of butterflies and beetles, the rich colours and spotted lustre of many tribes of insects.

There are parts also of animals ornamental, and the properties by which they are so, not subservient, that we know of, to any other purpose. The *irides* of most animals are very beautiful, without conducing at all, by their beauty, to the perfection of vision; and nature could in no part have employed her pencil to so much advantage, because no part presents itself so conspicuously to the observer, or communicates so great an effect to the whole aspect.

In plants, especially in the flowers of plants, the principle of beauty holds a still more considerable place in their composition; is still more confessed than in animals. Why, for one instance out of a thousand, does the corolla of the tulip when advanced to its size and maturity, change its colour? The purposes, so far as we can see, of vegetable nutrition, might have been carried on as well by continuing green. Or, if this could not be, consistent-

ly with the progress of vegetable life, why break into such a variety of colours? This is no proper effect of age, or of declension in the ascent of the sap; for that, like the autumnal tints, would have produced one colour in one leaf, with marks of fading and withering. It seems a lame account to call it, as it has been called, a disease of the plant. Is it not more probable, that this property, which is independent, as it should seem, of the wants and utilities of the plant, was calculated for beauty, intended for display?

A ground, I know, of objection, has been taken against this whole topic of argument, namely, that there is no such thing as beauty at all: in other words, that whatever is useful and familiar comes of course to be thought beautiful; and that things appear to be so, only by their alliance with these qualities. Our idea of beauty is capable of being so modified by habit, by fashion, by the experience of advantage or pleasure, and by associations arising out of that experience, that a question has been made whether it be not altogether generated by these causes, or would have any proper existence without them. It seems, however, a carrying of the conclusion too far, to deny the existence of the principle, viz. a native capacity of perceiving beauty, on account of the influence, or the varieties proceeding from that influence, to which it is subject: seeing that principles the most acknowledged, are liable to be affected in the same manner. I should rather argue thus: the question respects objects of sight. Now every other sense hath its distinction of agreeable and disagreeable. Some tastes offend the palate, others gratify it. In brutes and insects, this distinction is stronger, and more regular, than in man. Every horse, ox, sheep, swine, when at liberty to choose, and when in a natural state, that is, when not vitiated by habits forced upon it,

eafs and rejects the same plants. Many insects which feed upon particular plants, will rather die than change their appropriate leaf. All this looks like a determination in the sense itself to particular tastes. In like manner, smells affect the nose with sensations pleasurable or disgusting. Some sounds, or compositions of sound, delight the ear, others torture it. Habit can do much in all these cases, (and it is well for us that it can; for it is this power which reconciles us to many necessities,) but has the distinction, in the mean time, of agreeable and disagreeable, no foundation in the sense itself? What is true of the other senses, is most probably true of the eye, (the analogy is irresistable) viz. that there belongs to it an original constitution, fitted to perceive pleasure from some impressions, and pain from others.

I do not however know that the argument which alleges beauty as a final cause, rests upon this concession. We possess a sense of beauty, however we come by it. It in fact exists. Things are not indifferent to this sense: all objects do not suit it: many, which we see, are agreeable to it; many others disagreeable. It is certainly not the effect of habit upon the particular object, because the most agreeable objects are often the most rare; many, which are very common, continue to be offensive. If they be made supportable by habit, it is all which habit can do; they never become agreeable. If this sense, therefore, be acquired, it is a result; the produce of numerous and complicated actions of external objects upon the senses, and of the mind upon its sensations. With this *result* there must be a certain congruity to enable any particular object to please: and that congruity, we contend, is consulted in the *aspect* which is given to animal and vegetable bodies.

IV. The skin and covering of animals is that upon which their appearance chiefly depends, and it is that part which, perhaps, in all animals is most decorated; and most free from impurities. But were beauty, or agreeableness of aspect, entirely out of the question, there is another purpose answered by this integument, and by the collocation of the parts of the body beneath it, which is of still greater importance; and that purpose is *concealment*. Were it possible to view through the skin the mechanism of our bodies, the sight would frighten us out of our wits. "Durst we make a single movement," asks a lively French writer, "or stir a step from the place we were in, if we *saw* our blood circulating, the tendons pulling, the lungs blowing, the humours filtrating, and all the incomprehensible assemblage of fibres, tubes, pumps, valves, currents, pivots, which sustain an existence, at once so frail, and so presumptuous?"

V. Of animal bodies, considered as masses, there is another property, more curious than it is geneally thought to be; which is the faculty of *standing*: and it is more remarkable in two-legged animals than in quadrupeds, and, most of all, as being the tallest, and resting upon the smallest base, in man. There is more, I think, in the matter, than we are aware of. The statue of a man, placed loose upon its pedestal, would not be secure of standing half an hour. You are obliged to fix its feet to the block by bolts and solder, or the first shake, the first gust of wind, is sure to throw it down. Yet this statue shall express all the mechanical proportions of a living model. It is not therefore the mere figure, or merely placing the centre of gravity within the base, that is sufficient. Either the law of gravitation is suspended in favour of living substances, or something more is done for them, in order to enable them to uphold their posture.

There is no reason whatever to doubt, but that their parts descend by gravitation in the same manner as those of dead matter. The gift therefore appears to me to consist, in a faculty of perpetually shifting the centre of gravity, by a set, of obscure indeed, but of quick, balancing actions, so as to keep the line of direction, which is a line drawn from that centre to the ground, within its prescribed limits. Of these actions it may be observed, first, that they in part constitute what we call strength. The dead body drops down. The mere adjustment, therefore, of weight and pressure, which may be the same the moment after death as the moment before, does not support the column. In cases also of extreme weakness the patient cannot stand upright. Secondly; that these actions are only in a small degree voluntary. A man is seldom conscious of his voluntary powers in keeping himself upon his legs. A child learning to walk is the greatest posture-master in the world: but art, if it may be so called, sinks into habit; and he is soon able to poise himself in a great variety of attitudes without being sensible either of caution or effort. But still there must be an aptitude of parts upon which habit can thus attach; a previous capacity of motion which the animal is thus taught to exercise: and the facility, with which this exercise is acquired, forms one object of our admiration. What parts are principally employed, or in what manner each contributes its office, is, as hath already been confessed, difficult to explain. Perhaps the obscure motion of the bones of the feet may have their share in this effect. They are put in action by every slip or vaccillation of the body, and seem to assist in restoring its balance. Certain it is, that this circumstance in the structure of the foot, viz. its being composed of many small bones, applied to, and articulating with, one another, by diversely shaped surfaces, instead of be-

ing made of one piece, like the last of a shoe, is very remarkable. I suppose also that it would be difficult to stand firm upon stilts or wooden legs, though their base exactly imitated the figure and dimensions of the sole of the foot. The alternation of the joints, the knee joint bending backward, the hip joint forward; the flexibility, in every direction, of the spine, especially in the loins and neck, appear to be of great moment in preserving the equilibrium of the body. With respect to this last circumstance it is observable, that the vertebræ are so confined by ligaments as to allow no more slipping upon their bases, than what is just sufficient to break the shock which any violent motion may occasion to the body. A certain degree also of tension of the sinews appears to be essential to an erect posture; for it is by the loss of this, that the dead or paralytic body drops down. The whole is a wonderful result of combined powers, and of very complicated operations.

We have said that this property is the most worthy of observation in the *human* body: but a *bird*, resting upon its perch, or hopping upon a spray, affords no mean specimen of the same faculty. A chicken runs off as soon as it is hatched from the egg; yet a chicken, considered geometrically, and with relation to its centre of gravity, its line of direction, and its equilibrium, is a very irregular solid. Is this gift, therefore, or instruction? May it not be said to be with great attention, that nature hath balanced the body upon its pivots?

I observe also in the same *bird* a piece of useful mechanism of this kind. In the trussing of a fowl, upon bending the legs and thighs up towards the body, the cook finds that the claws close of their own accord. Now let it be remembered, that this is the position of the limbs, in which the bird rests upon its perch. And in this position

it sleeps in safety; for the claws do their office in keeping hold of the support, not by any exertion of voluntary power, which sleep might suspend, but by the traction of the tendons, in consequence of the attitude which the legs and thighs take by the bird sitting down, and to which the mere weight of the body gives the force that is necessary.

VI. Regarding the human body as a mass; regarding the general conformations which obtain in it; regarding, also, particular parts in respect to those conformations; we shall be led to observe what I call "interrupted analogies." The following are examples of what I mean by these terms: and I do not know how such critical deviations can, by any possible hypothesis, be accounted for, without design.

1. All the bones of the body are covered with a *periosteum*, except the teeth; where it ceases, and an enamel of ivory, which saws and files will hardly touch, comes into its place. No one can doubt of the use and propriety of this difference; of the "analogy" being thus "interrupted;" of the rule, which belongs to the conformation of the bones, stopping where it does stop: for, had so exquisitely sensible a membrane as the periosteum, invested the teeth, as it invests every other bone of the body, their action, necessary exposure, and irritation, would have subjected the animal to continual pain. General as it is, it was not the sort of integument which suited the teeth. What they stood in need of, was a strong, hard, insensible, defensive coat: and exactly such a covering is given to them, in the ivory enamel which adheres to their surface.

2. The scarf-skin, which clothes all the rest of the body, gives way, at the extremities of the toes and fingers, to *nails*. A man is only to look at his hand, to observe with what nicety and precision, that covering, which

extends over every other part, is here superseded by a different substance, and a different texture. Now, if either the rule had been necessary, or the deviation from it accidental, this effect would not be seen. When I speak of the rule being necessary, I mean the formation of the skin upon the surface being produced by a set of causes constituted without design, and acting, as all ignorant causes must act, by a general operation. Were this the case, no account could be given of the operation being suspended at the finger's ends, or on the back part of the fingers, and not on the fore part. On the other hand; if the deviation were accidental, an error, an anomalism; were it any thing else than settled by intention; we should meet with nails upon other parts of the body. They would be scattered over the surface, like warts or pimples.

3. All the great cavities of the body are inclosed by membranes except the *skull*. Why should not the brain be content with the same covering as that which serves for the other principal organs of the body? The heart, the lungs, the liver, the stomach, the bowels, have all soft integuments, and nothing else. The muscular coats are all soft and membranous. I can see a reason for this distinction in the final cause, but in no other. The importance of the brain to life, (which experience proves to be immediate,) and the extreme tenderness of its substance, make a solid case more necessary for it, than for any other part: and such a case the hardness of the skull supplies. When the smallest portion of this natural casquet is lost, how carefully, yet how imperfectly is it replaced by a plate of metal? If an anatomist should say, that this bony protection is not confined to the brain, but is extended along the course of the spine, I answer, that he adds strength to the argument. If he remark, that the chest also is fortified by bones, I reply, that I should have alleged this in-

stance myself, if the ribs had not appeared subservient to the purpose of motion, as well as defence. What distinguishes the skull from every other cavity is, that the bony covering completely surrounds its contents, and is calculated, not for motion, but solely for defence. Those hollows likewise, and inequalities, which we observe in the inside of the skull, and which exactly fit the folds of the brain, answer the important design of keeping the substance of the brain steady, and of guarding it against concussions.

CHAPTER XII.

COMPARATIVE ANATOMY.

WHENEVER we find a general plan pursued, yet with such variations in it, as are, in each case required by the particular exigency of the subject to which it is applied, we possess, in such plan and such adaptation, the strongest evidence, that can be afforded, of intelligence and design; an evidence, which the most completely excludes every other hypothesis. If the general plan proceeded from any fixed necessity in the nature of things, how could it accommodate itself to the various wants and uses which it had to serve under different circumstances, and on different occasions? Arkwright's mill was invented for the spinning of cotton. We see it employed for the spinning of wool, flax, and hemp, with such modifications o the original principle, such variety in the same plan, as the texture of those different materials rendered necessary. Of the machine's being put together with design, if it were possible to doubt, whilst we saw it only under one mode, and in one form; when we came to observe it in its different applications, with such changes of structure such additions, and supplements, as the special and particular use in each case demanded, we could not refuse any longer our assent to the proposition, "that intelligence, properly and strictly so called (including under that name, foresight, consideration, reference to utility) had been employed, as well in the primitive plan, as in the several changes and accomodations which it is made to undergo."

Very much of this reasoning is applicable to what has

been called *Comparative Anatomy.* In their general economy, in the outlines of the plan, in the construction as well as offices of their principal parts, there exists, between all large terrestrial animals, a close resemblance. In all life is sustained, and the body nourished, by nearly the same apparatus. The heart, the lungs, the stomach, the liver, the kidneys, are much alike in all. The same fluid (for no distinction of blood has been observed) circulates through their vessels, and nearly in the same order. The same cause, therefore, whatever that cause was, has been concerned in the origin; has governed the production of these different animal forms.

When we pass on to smaller animals, or to the inhabitants of a different element, the resemblance becomes more distant and more obscure, but still the plan accompanies us.

And what we can never enough commend, and which it is our business at present to exemplify, the plan is attended through all its varieties and deflections by subserviencies to special occasions and utilities.

I. The *covering* of different animals (though whether I am correct in classing this under their anatomy, I don't know) is the first thing which presents itself to our observation; and is in truth, both for its variety, and its suitableness to their several natures, as much to be admired as any part of their structure. We have bristles, hair, wool, furs, feathers, quills, prickles, scales; yet in this diversity both of material and form, we cannot change one animals coat for another, without evidently changing it for the worse: taking care however to remark, that these coverings are in many cases armour as well as clothing; intended for protection as well as warmth.

The *human* animal is the only one which is naked

and the only one can clothe itself. This is one of the properties which renders him an animal of all climates, and of all seasons. He can adapt the warmth or lightness of his covering to the temperature of his habitation. Had he been born with a fleece upon his back, although he might have been comforted by its warmth in high latitudes, it would have oppressed him by its weight and heat as the species spread towards the equator.

What art, however, does for men, nature has, in many instances, done for those animals which are incapable of art. Their clothing, of its own accord, changes with their necessities. This is particularly the case with that large tribe of quadrupeds which are covered with *furs*. Every dealer in hare-skins, and rabbit-skins, knows how much the fur is thickened by the approach of winter. It seems to be a part of the same constitution and the same design, that wool, in hot countries, degenerates, as it is called, but in truth (most happily for the animal's ease) passes into hair; whilst, on the contrary, that hair, in the dogs of the polar regions, is turned into wool, or something very like it. To which may be referred, what naturalists have remarked, that bears, wolves, foxes, hares, which do not take the water, have the fur much thicker on the back than the belly: whereas in the beaver it is the thickest upon the belly; as are the feathers in the waterfowl. We know the final cause of all this; and we know no other.

The *covering of birds* cannot escape the most vulgar observation. Its lightness, its smoothness, its warmth: the disposition of the feathers all inclined backward, the down about their stem, the overlapping of their tips, their different configuration in different parts, not to mention the variety of their colours, constitute a vestment for the body, so beautiful, and so appropriate

to the life which the animal is to lead, as that, I think, we should have had no conception of any thing equally perfect, if we had never seen it or can now imagine any thing more so. Let us suppose (what is possible only in supposition) a person who had never seen a bird, to be presented with a plucked pheasant, and bid to set his wits to work, how to contrive for it a covering which shall unite the qualities of warmth, levity, and least resistance to the air, and the highest degree of each; giving it also as much of beauty and ornament as he could afford. He is the person to behold the work of the Deity, in this part of his creation, with the sentiments which are due to it.

The commendation, which the general aspect of the feathered world seldom fails of exciting, will be increased by further examination. It is one of those cases in which the philosopher has more to admire, than the common observer. Every *feather* is a mechanical wonder. If we look at the quill, we find properties not easily brought together, strength and lightness. I know few things more remarkable, than the strength and lightness of the very pen, with which I am writing. If we cast our eye to the upper part of the stem, we see a material, made for the purpose, used in no other class of animals, and in no other part of birds; tough, light, pliant, elastic. The pith, also, which feeds the feather, is, amongst animal substances, sui generis; neither bone, flesh, membrane, nor tendon.

But the artificial part of a feather is the *beard*, or, as it is sometimes, I believe, called, the vane. By the beards are meant, what are fastened on each side the stem, and what constitute the breadth of the feather; what we usually strip off, from one side or both, when we make a pen. The seperate pieces, or laminæ, of which

the beard is composed, are called threads, sometimes filaments, or rays. Now the first thing which an attentive observer will remark is, how much stronger the beard of the feather shows itself to be, when pressed in a direction perpendicular to its plane, than when rubbed, either up or down, in the line of the stem; and he will soon discover the structure which occasions this difference, viz. that the laminæ whereof these beards are composed, are flat, and placed with their flat sides towards each other; by which means, whilst they *easily* bend for the approaching of each other, as any one may perceive by drawing his finger ever so lightly upwards, they are much harder to bend out of their plane, which is the direction in which they have to encounter the impulse and pressure of the air; and in which their strength is wanted, and put to the trial.

This is one particularity in the structure of a feather: a second is still more extraordinary. Whoever examines a feather, cannot help taking notice, that the threads or laminæ of which we have been speaking, in their natural state *unite;* that their union is something more than the mere apposition of loose surfaces; that they are not parted asunder without some degree of force; that nevertheless there is no glutinous cohesion between them; that, therefore, by some mechanical means or other, they catch or clasp among themselves, thereby giving to the beard or vane its closeness and compactness of texture. Nor is this all: when two laminæ, which have been separated by accident or force, are brought together again, they immediately *reclasp:* the connexion, whatever it was, is perfectly recovered, and the beard of the feather becomes as smooth and firm as if nothing had happened to it. Draw your finger down the feather, which is against the grain, and you break, probably, the junction of some of the con-

tiguous threads; draw your finger up the feather, and you restore all things to their former state. This is no common contrivance; and now for the mechanism by which it is effected. The threads or laminæ above mentioned are *interlaced* with one another; and the interlacing is performed by means of an infinite number of fibres or teeth, which the laminæ shoot forth *on each side*, and which hook and grapple together. A friend of mine counted fifty of these fibres in one twentieth of an inch. These fibres are crooked; but curved after a different manner; for those, which proceed from the thread on the side towards the extremity of the feather, are longer, more flexible, and bent downward: whereas those which proceed from the side towards the beginning or quill end of the feather are shorter, firmer, and turn upwards. The process then which takes place is as follows. When two laminæ are pressed together, so that these long fibres are forced far enough over the short ones *their* crooked parts fall into the cavity made by the crooked parts of the others; just as the latch that is fastened to a door, enters into the cavity of the catch fixed to the door post, and, there hooking itself, *fastens* the door: for it is properly in this manner, that one thread of a feather is fastened to the other.

This admirable structure of the feather, which it is easy to see with the microscope, succeeds perfectly for the use to which nature has designed it, which use was, not only that the laminæ might be united, but that when one thread or lamina has been separated from another by some external violence, it might be reclasped with sufficient facility and expedition.*

* The above account is taken from Memoirs for a Natural History of Animals by the Royal Academy of Paris, published 1701, p. 219.

In the *ostrich*, this apparatus of crotchets and fibres, of hooks and teeth, is wanting; and we see the consequence of the want. The filaments hang loose and separate from one another, forming only a kind of down; which constitution of the feathers, however it may fit them for the flowing honours of a lady's head-dress, may be reckoned an imperfection in the bird, inasmuch as wings, composed of these feathers, although they may greatly assist it in running, do not serve for flight.

But under the present division of our subject, our business with feathers is, as they are the *covering* of the bird. And herein a singular circumstance occurs. In the small order of birds which winter with us, from a snipe downwards, let the external colour of the feathers be what it will, their Creator has universally given them a bed of *black* down next their bodies. Black, we know, is the warmest colour: and the purpose here is, to *keep in* the heat, arising from the heart and circulation of the blood. It is further likewise remarkable, that this is not found in larger birds; for which there is also a reason. Small birds are much more exposed to the cold than large ones; forasmuch as they present, in proportion to their bulk, a much larger surface to the air. If a turkey was divided into a number of wrens, supposing the shape of the turkey and the wren to be similar, the surface of all the wrens would exceed the surface of the turkey, in the proportion of the length, breadth, (or, of any homologous line) of a turkey to that of a wren; which would be perhaps a proportion of ten to one. It was necessary therefore that small birds should be warmer clad than large ones, and this seems to be the expedient, by which that exigency is provided for.

II. In comparing different animals, I know no part of their structure which exhibits greater variety, or in that

variety, a nicer accommodation to their respective conveniency, than that which is seen in the different formations of their *mouths*. Whether the purpose be the reception of aliment merely, or the catching of prey, the picking up of seeds, the cropping of herbage, the extraction of juices, the suction of liquids, the breaking and grinding of food, the taste of that food, together with the respiration of air, and in conjunction with the utterance of sound; these various offices are assigned to this one part, and, in different species, provided for, as they are wanted, by its different constitution. In the human species, forasmuch as there are hands to convey the food to the mouth, the mouth is flat, and by reason of its flatness fitted only for *reception*: whereas the projecting jaws, the wide rictus, the pointed teeth, of the dog and his affinities, enable them to apply their mouths to *snatch and seize* the objects of their pursuit. The full lips, the rough tongue, the corrugated cartilaginous palate, the broad cutting teeth, of the ox, the deer, the horse and the sheep, qualify this tribe for *browsing* upon their pasture; either gathering large mouthfuls at once, where the grass is long, which is the case with the ox in particular; or biting close, where it is short, which the horse and the sheep are able to do, in a degree that one could hardly expect. The retired under jaw of a swine *works in the ground*, after the protruding snout, like a prong or ploughshare, has made its way to the roots upon which it feeds. A conformation, so happy, was not the gift of chance.

In *birds* this organ assumes a new character; new both in substance and in form, but, in both, wonderfully adapted to the wants and uses of a distinct mode of existence. We have, no longer, the fleshy lips, the teeth of enamelled bone; but we have, in the place of these two parts, and to perform the office of both, a hard substance

(of the same nature with that which composes the nails, claws and hoofs of quadrupeds) cut out into proper shapes, and mechanically suited to the actions which are wanted. The sharp edge and tempered point of the *sparrow's* bill, picks almost every kind of seed from its concealment in the plant; and not only so, but hulls the grain, breaks and shatters the coats of the seed, in order to get at the kernel. The *hooked* beak of the hawk tribe, separates the flesh from the bones of the animals which it feeds upon, almost with the cleanness and precision of a dissector's knife. (The butcher bird, transfixes its prey upon the spike of a thorn, whilst it picks its bones.) In some birds of this class, we have the *cross* bill, i. e. both the upper and lower bill hooked, and their tips crossing. The *spoon* bill, enables the goose to graze, to collect its food from the bottom of pools, or to seek it amidst the soft or liquid substances with which it is mixed. The *long* tapering bill of the snipe and woodcock, penetrates still deeper into moist earth, which is the bed in which the food of that species is lodged. This is exactly the instrument which the animal wanted. It did not want strength in its bill, which was inconsistent with the slender form of the animal's neck, as well as unnecessary for the kind of aliment upon which it subsists; but it wanted length to reach its object.

But the species of bill which belongs to birds that live by *suction*, deserves to be described in its particular relation to that office. They are what naturalists call serrated or dentated bills; the inside of them, towards the edge, being thickly set with parallel or concentric rows, of short, strong, sharp-pointed prickles. These, though they should be called teeth, are not for the purpose of mastication, like the teeth of quadrupeds; nor yet, as in fish, for the seizing and retaining of their prey; but for a quite

different use. They form a filter. The *duck*, by means of them, discusses the mud; examining, with great accuracy, the puddle, the brake, every mixture which is likely to contain her food. The operation is thus carried on. The liquid or semi-liquid substances, in which the animal has plunged her bill, she draws, by the action of her lungs, through the narrow interstices which lie between these teeth; catching, as the stream passes across her beak, whatever it may happen to bring along with it, that proves agreeable to her choice, and easily dismissing all the rest. Now suppose the purpose to have been, out of a mass of confused and heterogeneous substances, to separate for the use of the animal, or rather to enable the animal to separate for its own, those few particles which suited its taste and digestion; what more artificial, or more commodious instrument of selection, could have been given to it, than this natural filter? It has been observed also, what must enable the bird to choose and distinguish with greater acuteness, as well, probably, as what increases its gratification and its luxury, that the bills of this species are furnished with large nerves, that they are covered with a skin, and that the nerves run down to the very extremity. In the curlew, woodcock, and snipe, there are *three pairs* of nerves, equal almost to the optic nerve in thickness, which pass first along the roof of the mouth, and then along the upper chap, down to the point of the bill, long as the bill is.

But to return to the train of our observations. The similitude between the bills of birds and the mouths of quadrupeds, is exactly such, as, for the sake of the argument, might be wished for. It is near enough to show the continuation of the same plan: it is remote enough to exclude the supposition of the difference being produced by action or use. A more prominent contour, or a wider

gape, might be resolved into the effect of continued efforts on the part of the species, to thrust out the mouth, or open it to the stretch. But by what course of action, or exercise, or endeavour, shall we get rid of the lips, the gums, the teeth; and acquire, in the place of them, pincers of horn? By what habit shall we so completely change, not only the shape of the part, but the substance of which it is composed? The truth is, if we had seen no other than the mouths of quadrupeds, we should have thought no other could have been formed: little could we have supposed, that all the purposes of a mouth, furnished with lips, and armed with teeth, could be answered by an instrument which had none of these; could be supplied, and that with many additional advantages, by the hardness, and sharpness, and figure, of the bills of birds.

Every thing about the animal *mouth* is mechanical. The teeth of fish, have their points turned backwards, like the teeth of a wool or cotton-card. The teeth of lobsters, work one against another, like the sides of a pair of shears. In many insects, the mouth is converted into a pump or sucker, fitted at the end sometimes with a wimble, sometimes with a forceps; by which double provision, viz. of the tube and the penetrating form of the point, the insect first bores through the integuments of its prey, and then extracts the juices. And, what is most extraordinary of all, one sort of mouth, as the occasion requires, shall be changed into another sort. The caterpillar could not live without teeth; in several species, the butterfly formed from it, could not use them. The old teeth, therefore, are cast off with the exuviæ of the grub; a new and totally different apparatus assumes their place in the fly. Amidst these novelties of form, we sometimes forget that it is, all the while, the animal's *mouth*; that, whether it be lips, or teeth, or bill, or beak, or shears, or pump, it is the same

part diversified: and it is also remarkable, that under all the varieties of configuration with which we are acquainted, and which are very great, the organs of taste and smelling are situated near each other.

III. To the mouth adjoins the *gullet;* in this part also, comparative anatomy discovers a difference of structure adapted to the different necessities of the animal. In brutes, because the posture of their neck conduces little to the passage of the aliments, the fibres of the gullet, which act in this business, run in two close spiral lines, crossing each other: in men, these fibres run only a little obliquely from the upper end of the œsophagus to the stomach, into which, by a gentle contraction, they easily transmit the descending morsels; that is to say, for the more laborious deglutition of animals, which thrust their food *up* instead of *down*, and also through a longer passage, a proportionably more powerful apparatus of muscles is provided; more powerful, not merely by the strength of the fibres, which might be attributed to the greater exercise of their force, but in their collocation, which is a determinate circumstance, and must have been original.

IV. The gullet leads to the *intestines:* here, likewise, as before, comparing quadrupeds with man, under a general similitude we meet with appropriate differences. The valvulæ conniventes, or, as they are by some called, the semilunar valves, found in the human intestine, are wanting in that of brutes. These are wrinkles or plaits of the innermost coat of the guts, the effect of which, is to retard the progress of the food through the alimentary canal. It is easy to understand how much more necessary such a provision may be to the body of an animal of an erect posture, and in which, consequently, the weight of the food is added to the action of the intestine, than in

that of a quadruped, in which the course of the food, from its entrance to its exit, is nearly horizontal: but it is impossible to assign any cause, except the final cause, for this distinction actually taking place. So far as depends upon the action of the part, this structure was more to be expected in a quadruped than in a man. In truth, it must, in both, have been formed, not by action, but in direct opposition to action, and to pressure: but the opposition, which would arise from pressure, is greater in the upright trunk than in any other. That theory, therefore, is pointedly contradicted by the example before us. The structure is found, where its generation, according to the method by which the theorist would have it generated, is the most difficult; but *(observe)* it is found, where its effect is most useful.

The different length of the intestines in carnivorous and herbivorous animals has been noticed on a former occasion. The shortest, I believe, is that of some birds of prey, in which the intestinal canal is little more than a straight passage from the mouth to the vent. The longest is in the deer kind. The intestines of a Canadian stag, four feet high, measured ninety-six feet.* The intestine of a sheep, unravelled, measures thirty times the length of the body. The intestine of a wild cat is only three times the length of the body. Universally, where the substance upon which the animal feeds, is of slow concoction, or yields its chyle with more difficulty, there the passage is circuitous and dilatory, that time and space may be allowed for the change and the absorption which are necessary. Where the food is soon dissolved, or already half assimilated, an unnecessary, or, perhaps, hurtful detention is avoided, by giving to it a shorter and a readier route.

V. In comparing the *bones* of different animals, we

* Mem. of Acad. Paris, 1701, p. 170.

are struck, in the bones of birds, with a *propriety*, which could only proceed from the wisdom of an intelligent and designing Creator. In the bones of an animal which is to fly, the two qualities required, are strength and lightness. Wherein, therefore, do the bones of birds (I speak of the cylindrical bones) differ, in these respects, from the bones of quadrupeds? In three properties, first, their cavities are much larger in proportion to the weight of the bone, than in those of quadrupeds: secondly, these cavities are empty: thirdly, the shell is of a firmer texture, than is the substance of other bones. It is easy to observe these particulars, even in picking the wing or leg of a chicken. Now, the weight being the same, the diameter, it is evident, will be greater in a hollow bone than a solid one; and, with the diameter, as every mathematician can prove, is increased, cæteris paribus, the strength of the cylinder, or its resistance to breaking. In a word; a bone of the *same weight* would not have been so strong in any other form; and, to have made it heavier, would have incommoded the animal's flight. Yet this form could not be acquired by use, or the bone become hollow and tubular by exercise. What appetency could excavate a bone?

VI. The *lungs* also of birds, as compared with the lungs of quadrupeds, contain in them a provision, distinguishingly calculated for this same purpose of levitation; namely, a communication (not fouud in other kinds of animals) between the air-vessels of the lungs and the cavities of the body: so that by the intromission of air from one to the other, at the will, as it should seem, of the animal, its body can be occasionally puffed out, and its tendency to descend in the air, or its specific gravity, made less. The bodies of birds are blown up from their lungs, which no other animal bodies are; and thus rendered buoyant.

VII. All birds are *oviparous*. This, likewise, carries on the work of gestation, with as little increase as possible of the weight of the body. A gravid uterus would have been a troublesome burthen to a bird in its flight. The advantage in this respect, of an oviparous procreation is, that, whilst the whole brood are hatched together, the eggs are excluded singly, and at considerable intervals. Ten, fifteen, or twenty young birds may be produced in one cletch or covey, yet the parent bird has never been encumbered by the load of more than one full grown egg at one time.

VIII. A principal topic of comparison between animals, is in their *instruments of motion*. These come before us under three divisions, feet, wings, and fins. I desire any man to say, which of the three is best fitted for its use: or whether the same consummate art be not conspicuous in them all. The constitution of the elements, in which the motion is to be performed, is very different. The animal action must necessarily follow that constitution. The Creator therefore, if we might so speak, had to prepare for different situations, for different difficulties: yet the purpose is accomplisded not less successfully, in one case than the other. And, as between *wings* and the corresponding limbs of quadrupeds, it is accomplished without deserting the general idea. The idea is modified, not deserted. Strip a wing of its feathers, and it bears no obscure resemblance to the fore leg of a quadruped. The articulations at the shoulder and the cubitus are much alike; and, what is a closer circumstance, in both cases the upper part of the limb consists of a single bone, the lower part of two.

But, fitted up with its furniture of feathers and quills, it becomes a wonderful instrument; more artificial than its first appearance indicates, though that be very striking:

at least, the use, which the bird makes of its wings in flying, is more complicated, and more curious, than is generally known. One thing is certain; that, if the flapping of the wings in flight were no more than the reciprocal motion of the same surface in opposite directions, either upwards and downwards, or estimated in any oblique line, the bird would lose as much by one motion, as she gained by another. The skylark could never ascend by such an action as this; for, though the stroke upon the air by the under side of her wing would carry her up, the stroke from the upper side, when she raised her wing again, would bring her down. In order, therefore, to account for the advantage which the bird derives from her wings, it is necessary to suppose, that the surface of the wing, measured upon the same plane, is contracted, whilst the wing is drawn up; and let out to its full expansion, when it descends upon the air for the purpose of moving the body by the reaction of that element. Now the form and structure of the wing, its external convexity, the disposition, and particularly the overlapping, of its larger feathers, the action of the muscles and joints of the pinions, are all adapted to this alternate adjustment of its shape and dimensions. Such a twist, for instance, or semirotatory motion, is given to the great feathers of the wing, that they strike the air with their flat side, but rise from the stroke slantwise. The turning of the oar in rowing, whilst the rower advances his hand for a new stroke, is a similar operation to that of the feather, and takes its name from the resemblance. I believe that this faculty is not found in the great feathers of the tail. This is the place also for observing, that the pinions are so set on upon the body, as to bring down the wings, not vertically, but in a direction obliquely tending towards the tail: which motion, by virtue of the common resolution of forces, does two things at

the same time; supports the body in the air, and carries it forward.

The *steerage* of a bird in its flight is effected partly by the wings, but, in a principal degree, by the tail. And herein we meet with a circumstance not a little remarkable. Birds with long legs have short tails; and, in their flight, place their legs close to their bodies, at the same time stretching them out backwards as far as they can. In this position the legs extend beyond the rump, and become the rudder; supplying that steerage which the tail could not.

From the *wings* of birds, the transition is easy to the *fins* of fish. They are both, to their respective tribes, the instruments of their motion; but, in the work which they have to do, there is a considerable difference, founded in this circumstance. Fish, unlike birds, have very nearly the same specific gravity with the element in which they move. In the case of fish, therefore, there is little or no weight to bear up: what is wanted is only an impulse, sufficient to carry the body through a resisting medium, or to maintain the posture, or to support or restore the balance of the body, which is always the most unsteady where there is no weight to sink it. For these offices the fins are as large as necessary, though much smaller than wings, their action mechanical, their position, and the muscles by which they are moved, in the highest degree convenient. The following short account of some experiments upon fish, made for the purpose of ascertaining the use of their fins, will be the best confirmation of what we assert. In most fish, beside the great fin, the tail, we find two pair of fins upon the sides, two single fins upon the back, and one upon the belly, or rather between the belly and the tail. The *balancing* use of these organs is proved in this manner. Of the large-headed fish, if you cut off

the pectoral fins, i. e. the pair which lie close behind the gills, the head falls prone to the bottom : if the right pectoral fin only be cut off, the fish leans to that side ; if the ventral fin on the same side be cut away, then it loses its equilibrium entirely : if the dorsal and ventral fins be cut off, the fish reels to the right and left. When the fish dies, that is, when the fins cease to play, the belly turns upwards. The use of the same parts for *motion* is seen in the following observations upon them when put in action. The pectoral, and more particularly the ventral fins, serve to *raise and depress* the fish : when the fish desires to have a *retrograde* motion, a stroke forward with the pectoral fin effectually produces it : if the fish desire to *turn* either way, a single blow with the tail the opposite way, sends it round at once : if the tail strike both ways, the motion produced by the double lash is *progressive;* and enables the fish to dart forward with an astonishing velocity.* The result is, not only, in some cases, the most rapid, but, in all cases, the most gentle, pliant, easy animal motion, with which we are acquainted. However, when the tail is cut off, the fish loses all motion, and gives itself up to where the water impels it. The rest of the fins, therefore, so far as respects motion, seem to be merely subsidiary to this. In their mechanical use, the anal fin may be reckoned the keel ; the ventral fins, out-riggers ; the pectoral muscles, the oars : and if there be any similitude between these parts of a boat and a fish, observe, that it is not the resemblance of imitation, but the likeness which arises from applying similar mechanical means to the same purpose.

We have seen that the *tail* in the fish is the great instrument of motion. Now, in cetaceous or warm-blooded

* Goldsmith's Hist. of An. Nat. vol. vi. p. 154.

fish, which are obliged to rise every two or three minutes to the surface to take breath, the tail, unlike what it is in other fish, is horizontal; its stroke, consequently, perpendicular to the horizon, which is the right direction for sending the fish to the top, or carrying it down to the bottom.

Regarding animals in their instruments of motion, we have only followed the comparison through the first great division of animals into beasts, birds, and fish. If it were our intention to pursue the consideration further, I should take in that generic distinction amongst birds, the *web foot* of water fowl. It is an instance which may be pointed out to a child, The utility of the web to water fowl, the inutility to land fowl, are so obvious, that it seems impossible to notice the difference without acknowledging the design. I am at a loss to know how those who deny the agency of an intelligent Creator, dispose of this example. There is nothing in the action of swimming, as carried on by a bird upon the surface of the water, that should generate a membrane between the toes. As to that membrane, it is an exercise of constant resistance. The only supposition I can think of is, that all birds have been originally water fowl, and web footed; that sparrows, hawks, linnets, &c. which frequent the land, have, in process of time, and in the course of many generations, had this part worn away by treading upon hard ground. To such evasive assumptions must atheism always have recourse; and, after all, it confesses that the structure of the feet of birds, in their original form, was critically adapted to their original destination. The web feet of amphibious quadrupeds, seals, otters, &c. fall under the same observation.

IX. The *five senses* are common to most large animals: nor have we much difference to remark in their constitu-

tion; or much, however, which is referable to mechanism.

The superior sagacity of animals which hunt their prey, and which, consequently, depend for their livelihood upon their *nose*, is well known in its use; but not at all known in the organization which produces it.

The external *ears* of beasts of prey, of lions, tigers, wolves, have their trumpet part or concavity standing forwards, to seize the sounds which are before them, viz. the sounds of the animals which they pursue or watch. The ears of animals of flight are turned backward, to give notice of the approach of their enemy from behind, when he may steal upon them unseen. This is a critical distinction; and is mechanical: but it may be suggested, and, I think, not without probability, that it is the effect of continued habit.

The *eyes* of animals which follow their prey by night, as cats, owls, &c. possess a faculty, not given to those of other species; namely, of closing the pupil *entirely*. The final cause of which seems to be this. It was necessary for such animals to be able to descry objects with very small degrees of light. This capacity depended upon the superior sensibility of the retina; that is, upon its being affected by the most feeble impulses. But that tenderness of structure, which rendered the membrane thus exquisitely sensible, rendered it also liable to be offended by the access of stronger degrees of light. The contractile range therefore of the pupil is increased in these animals, so as to enable them to close the aperture entirely; which includes the power of diminishing it in every degree; whereby at all times such portions, and only such portions of light are admitted, as may be received without injury to the sense.

There appears to be also in the figure, and in some

properties of the pupil of the eye, an appropriate relation to the wants of different animals. In horses, oxen, goats, sheep, the pupil of the eye is elliptical; the transverse axis being horizontal; by which structure, although the eye be placed on the side of the head, the anterior elongation of the pupil catches the forward rays, or those which come from objects immediately in front of the animal's face.

CHAPTER XIII.

PECULIAR ORGANIZATIONS.

I BELIEVE that all the instances which I shall collect under this title, might, consistently enough with technical language, have been placed under the head of *Comparative Anatomy*. But there appears to me an impropriety in the use which that term hath obtained: it being, in some sort, absurd, to call that a case of Comparative Anatomy, in which there is nothing to "compare;" in which a conformation is found in one animal, which hath nothing properly answering to it in another. Of this kind are the examples which I have to propose in the present chapter; and the reader will see that, though some of them be the strongest, perhaps, he will meet with under any division of our subject, they must necessarily be of an unconnected and miscellaneous nature. To dispose them, however, into some sort of order, we will notice, first, particularities of structure which belong to quadrupeds, birds, and fish, as such, or to many of the kinds included in these classes of animals; and then, such particularities as are confined to one or two species.

I. Along each side of the neck of large *quadrupeds*, runs a stiff robust cartilage, which butchers call the pax wax. No person can carve the upper end of a crop of beef without driving his knife against it. It is a tough, strong, tendinous substance, braced from the head to the middle of the back: its office is to assist in supporting the weight of the head. It is a mechanical provision, of which this is the undisputed use; and it is sufficient, and not more than sufficient, for the purpose which it has to execute. The head of an ox or a horse is a heavy weight, acting at the end of a long lever, (consequently with a great purchase,) and in a direction nearly perpendicular to the joints of the supporting neck. From such a force, so advantageously applied, the bones of the neck would be in constant danger of dislocation, if they were not fortified by this strong tape. No such organ is found in the human subject, because, from the erect position of the head, (the pressure of it acting nearly in the direction of the spine,) the junction of the vertebræ appears to be sufficiently secure without it. The care of the Creator is seen where it is wanted. This cautionary expedient is limited to quadrupeds.

II. The oil with which *birds* prune their feathers, and the organ which supplies it, is a specific provision for the winged creation. On each side of the rump of birds is observed a small nipple, yielding upon pressure a butter-like substance, which the bird extracts by pinching the pap with its bill. With this oil or ointment, thus procured, the bird dresses its coat; and repeats the action as often as its own sensations teach it that it is in any part wanted, or as the excretion may be sufficient for the expense. The gland, the pap, the nature and quality of the excreted substance, the manner of obtaining it from its lodgment in the body, the application of it when obtained, form,

collectively, an evidence of intention, which it is not easy to withstand. Nothing similar to it is found in unfeathered animals. What blind conatus of nature should produce it in birds; should not produce it in beasts?

III. The air bladder also of a *fish*, affords a plain and direct instance, not only of contrivance, but strictly of that species of contrivance, which we denominate mechanical. It is a philosophical apparatus in the body of an animal. The principle of the contrivance is clear: the application of the principle is also clear. The use of the organ to sustain, and, at will, also to elevate, the body of the fish in the water, is proved by observing, what has been tried, that, when the bladder is burst, the fish grovels at the bottom; and also, that flounders, soles, skaits, which are without the air bladder, seldom rise in the water, and that, with effort. The manner in which the purpose is attained, and the suitableness of the means to the end, are not difficult to be apprehended. The rising and sinking of a fish in water, so far as it is independent of the stroke of the fins and tail, can only be regulated by the specific gravity of the body. When the bladder contained in the body of the fish, is contracted, which the fish probably possesses a muscular power of doing, the bulk of the fish is contracted along with it; whereby since the absolute weight remains the same, the specific gravity, which is the sinking force, is increased, and the fish descends: on the contrary, when in consequence of the relaxation of the muscles, the elasticity of the inclosed, and now compressed air, restores the dimensions of the bladder, the tendency downwards becomes proportionably less than it was before, or is turned into a contrary tendency. These are known properties of bodies immersed in a fluid. The enamelled figures, or little glass bubbles, in a jar of water, are made to rise and fall by the same

artifice. A diving machine might be made to ascend and descend upon the like principle; namely, by introducing into the inside of it an air vessel, which by its contraction would diminish, and by its distension enlarge, the bulk of the machine itself, and thus render it specifically heavier, or specifically lighter, than the water which surrounds it. Suppose this to be done; and the artist to solicit a patent for his invention. The inspectors of the model, whatever they might think of the use or value of the contrivance, could, by no possibility, entertain a question in their minds, whether it were a contrivance or not. No reason has ever been assigned, no reason can be assigned, why the conclusion is not as certain in the fish, as in the machine; why the argument is not as firm, in one case as the other.

It would be very worthy of inquiry, if it were possible to discover, by what method an animal, which lives constantly in water, is able to supply a repository of air. The expedient, whatever it be, forms part, and perhaps the most curious part, of the provision. Nothing similar to the air bladder is found in land animals; and a life in the water has no natural tendency to produce a bag of air. Nothing can be further from an acquired organization than this is.

These examples mark the attention of the Creator to three great kingdoms of his animal creation, and to their constitution as such. The example which stands next in point of generality, belonging to a large tribe of animals, or rather to various species of that tribe, is the poisonous tooth of serpents.

I. The *fang of a viper* is a clear and curious example of mechanical contrivance. It is a perforated tooth, loose at the root; in its quiet state lying down flat upon the jaw, but furnished with a muscle, which, with a jerk,

by the pluck as it were of a string, suddenly erects it. Under the tooth, close to its root, and communicating with the perforation, lies a small bag containing the venom. When the fang is raised, the closing of the jaw presses its root against the bag underneath; and the force of this compression sends out the fluid, and, with a considerable impetus, through the tube in the middle of the tooth. What more unequivocal or effectual apparatus could be devised, for the double purpose of at once inflicting the wound and injecting the poison? Yet, though lodged in the mouth, it is so constituted, as, in its inoffensive and quiescent state, not to interfere with the animal's ordinary office of receiving its food. It has been observed also, that none of the harmless serpents, the black snake, the blind worm, &c. have these fangs, but teeth of an equal size, not moveable, as this is, but fixed into the jaw.

II. In being the property of several different species, the preceding example is resembled by that which I shall next mention, which is the *bag of the opossum.* This is a mechanical contrivance, most properly so called. The simplicity of the expedient renders the contrivance more obvious than many others; and by no means less certain. A false skin under the belly of the animal, forms a pouch, into which the young litter are received at their birth; where they have an easy and constant access to the teats; in which they are transported by the dam from place to place; where they are at liberty to run in and out, and where they find a refuge from surprise and danger. It is their cradle, their conveyance, and their asylum. Can the use of this structure be doubted of? Nor is it a mere doubling of the skin, but it is a new organ, furnished with bones and muscles of its own. Two bones are placed before the os pubis, and joined to that bone as their base. These support and give a fixture to the muscles, which

serve to open the bag. To these muscles there are antagonists, which serve in the same manner to shut it: and this office they perform so exactly, that, in the living animal, the opening can scarcely be discerned, except when the sides are forcibly drawn asunder.* Is there any action in this part of the animal, any process arising from that action, by which these members could be formed? Any account to be given of the formation, except design?

III. As a particularity, yet appertaining to more species than one: and also as strictly mechanical; we may notice a circumstance in the structure of the *claws* of certain birds. The middle claw of the heron and cormorant, is toothed and notched like a saw. These birds are great fishers, and these notches assist them in holding their slippery prey. The use is evident; but the structure such, as cannot at all be accounted for by the effort of the animal, or the exercise of the part. Some other fishing birds have these notches in their *bills;* and for the same purpose. The gannet, or Soland goose, has the side of its bill irregularly jagged, that it may hold its prey the faster. Nor can the structure in this, more than in the former case, arise from the manner of employing the part. The smooth surfaces, and soft flesh of fish, were less likely to notch the bills of birds, than the hard bodies upon which many other species feed.

We now come to particularities strictly so called, as being limited to a single species of animal. Of these I shall take one from a quadruped and one from a bird.

I. The *stomach of the camel* is well known to retain large quantities of water, and to retain it unchanged for a considerable length of time. This property qualifies it

* Goldsmith's Nat. Hist. vol. iv. p. 144.

for living in the desert. Let us see, therefore, what is the internal organization, upon which a faculty, so rare and beneficial, depends. A number of distinct sacks or bags (in a dromedary thirty of these have been counted) are observed to lie between the membranes of the second stomach, and open into the stomach near the top by small square apertures. Through these orifices, after the stomach is full, the annexed bags are filled from it. And the water so deposited, is, in the first place, not liable to pass into the intestines; in the second place, is kept separate from the solid aliment; and, in the third place, is out of the reach of the digestive action of the stomach, or of mixture with the gastric juice. It appears probable, or rather certain, that the animal, by the conformation of its muscles, possesses the power of squeezing back this water from the adjacent bags into the stomach, whenever thirst excites it to put this power in action.

II. The *tongue of the wood-pecker*, is one of those singularities, which nature presents us with, when a singular purpose is to be answered. It is a particular instrument for a particular use; and what else but design ever produces such? The wood-pecker lives chiefly upon insects, lodged in the bodies of decayed or decaying trees. For the purpose of boring into the wood, it is furnished with a bill, straight, hard, angular, and sharp. When, by means of this piercer, it has reached the cells of the insects, than comes the office of its tongue; which tongue is first, of such a length that the bird can dart it out three or four inches from the bill, in this respect differing greatly from every other species of bird; in the second place, it is tipped with a stiff, sharp, bony thorn; and, in the third place, which appears to me the most remarkable property of all, this tip is dentated on both sides, like the beard of

an arrow or the barb of a hook. The description of the part declares its use. The bird, having exposed the retreats of the insects by the assistance of its bill, with a motion inconceivably quick, launches out at them this long tongue; transfixes them upon the barbed needle at the end of it; and thus draws its prey within its mouth. If this be not mechanism, what is? Should it be said, that, by continual endeavours to shoot out the tongue to the stretch, the wood-pecker species may by degrees have lengthened the organ itself, beyond that of other birds, what account can be given of its form; of its tip? How, in particular, did it get its barbs, its dentation? These barbs, in my opinion, wherever they occur, are decisive proofs of mechanical contrivance.

III. I shall add one more example for the sake of its novelty. It is always an agreeable discovery, when, having remarked in an animal an extraordinary structure, we come at length to find out an unexpected use for it. The following narrative which Goldsmith has taken from Buffon, furnishes an instance of this kind. The babyrouessa or Indian hog, a species of wild boar found in the East-Indies, has two *bent* teeth, more than half a yard long, growing upwards, and, which is the singularity, from the upper jaw. These instruments are not wanted for defence, that service being provided for by two tusks issuing from the under jaw, and resembling those of the common boar. Nor does the animal use them for defence. They might seem, therefore, to be both a superfluity and an incumbrance. But observe the event. The animal hitches one of these bent upper teeth upon the branch of a tree, and then suffers its whole body to swing from it. This is its manner of taking repose, and of consulting for its

safety. It continues the whole night suspended by its tooth, both easy in its posture, and secure; being out of the reach of animals which hunt it for prey.*

* Goldsmith's Nat. Hist. vol. iii. p. 195.

CHAPTER XIV.

PROSPECTIVE CONTRIVANCES.

I CAN hardly image to myself a more distinguishing mark, and, consequently, a more certain proof of design, than *preparation*, i. e. the providing of things beforehand, which are not to be used until a considerable time afterwards; for this implies a contemplation of the future, which belongs only to intelligence.

Of these prospective contrivances the bodies of animals furnish various examples.

I. The human teeth afford an instance, not only of prospective contrivance, but of the completion of the contrivance being designedly suspended. They are formed within the gums, and there they stop: the fact being, that their further advance to maturity would not only be useless to the new-born animal, but extremely in its way; as it is evident that the act of *sucking*, by which it is for some time to be nourished, will be performed with more ease both to the nurse and to the infant, whilst the inside of the mouth, and edges of the gums, are smooth and soft, than if set with hard pointed bones. By the time they are wanted, the teeth are ready. They have been lodged

within the gums for some months past, but detained, as it were, in their sockets, so long as their further protrusion would interfere with the office to which the mouth is destined. Nature, namely, that intelligence which was employed in creation, looked beyond the first year of the infant's life; yet, whilst she was providing for functions which were after that term to become necessary, was careful not to incommode those which preceded them. What renders it more probable that this is the effect of design, is that the teeth are imperfect, whilst all other parts of the mouth are perfect. The lips are perfect, the tongue is perfect; the cheeks, the jaws, the palate, the pharynx, the larynx, are all perfect. The teeth alone are not so. This is the fact with respect to the human mouth: the fact also is, that the parts above enumerated, are called into use from the beginning; whereas the teeth would be only so many obstacles and annoyances, if they were there. When a contrary order is necessary, a contrary order prevails. In the worm of the beetle, as hatched from the egg, the teeth are the first things which arrive at perfection. The insect begins to gnaw as soon as it escapes from the shell, though its other parts be only gradually advancing to their maturity.

What has been observed of the teeth, is true of the *horns* of animals; and for the same reason. The horn of a calf or lamb does not bud, or at least does not sprout to any considerable length, until the animal be capable of browsing upon its pasture; because such a substance upon the forehead of the young animal, would very much incommode the teat of the dam in the office of giving suck.

But in the case of the *teeth*, of the human teeth at least, the prospective contrivance looks still further. A succession of crops is provided, and provided from the

beginning; a second tier being originally formed beneath the first, which do not come into use till several years afterwards. And this double or suppletory provision meets a difficulty in the mechanism of the mouth, which would have appeared almost insurmountable. The expansion of the jaw, (the consequence of the proportionable growth of the animal, and of its skull) necessarily separates the teeth of the first set, however compactly disposed, to a distance from one another, which would be very inconvenient. In due time therefore, i. e. when the jaw has attained a great part of its dimensions, a new set of teeth spring up, (loosening and pushing out the old ones before them) more exactly fitted to the space which they are to occupy, and rising also in such close ranks, as to allow for any extension of line which the subsequent enlargement of the head may occasion.

II. It is not very easy to conceive a more evidently prospective contrivance, than that which, in all viviparous animals, is found in the *milk* of the female parent. At the moment the young animal enters the world, there is its maintenance ready for it. The particulars to be remarked in this economy are neither few nor slight. We have, first, the nutritious quality of the fluid, unlike, in this respect, every other excretion of the body; and in which nature hitherto remains unimitated, neither cookery nor chymistry having been able to make milk out of grass: we have, secondly, the organ for its reception and retention: we have, thirdly, the excretory duct, annexed to it: and we have, lastly, the determination of the milk to the breast, at the particular juncture when it is about to be wanted. We have all these properties in the subject before us; and they are all indications of design. The last circumstance is the strongest of any. If I had been to guess beforehand, I should have conjectured, that, at the

time when there was an extraordinary demand of nourishment in one part of the system, there would be the least likelihood of a redundancy to supply another part. The advanced pregnancy of the female has no intelligible tendency to fill the breast with milk. The lacteal system is a constant wonder: and it adds to other causes of our admiration, that the number of the teats or paps in each species is found to bear a proportion to the number of the young. In the sow, the bitch, the rabbit, the cat, the rat, which have numerous litters, the paps are numerous and are disposed along the whole length of the belly: in the cow and mare they are few. The most simple account of this, is to refer it to a designing Creator.

But, in the argument before us, we are entitled to consider not only animal bodies when framed, but the circumstances under which they are framed. And, in this view of the subject, the constitution of many of their parts, is, most strictly, prospective.

III. The eye is of no use, at the time when it is formed. It is an optical instrument made in a dungeon; constructed for the refraction of light to a focus, and perfect for its purpose, before a ray of light has had access to it; geometrically adapted to the properties and action of an element, with which it has no communication. It is about, indeed, to enter into that communication; and this is precisely the thing which evidences intention. It is *providing* for the *future* in the closest sense which can be given to these terms; for it is providing for a future change: not for the then subsisting condition of the animal; not for any gradual progress or advance in that same condition; but for a new state, the consequence of a great and sudden alteration which the animal is to undergo at its birth. Is it to be believed that the eye was formed, or, which is the same thing, that the series of causes was fixed by

which the eye is formed, without a view to this change; without a prospect of that condition, in which its fabric, of no use at present, is about to be of the greatest; without a consideration of the qualities of that element; hitherto entirely excluded, but with which it was hereafter to hold so intimate a relation? A young man makes a pair of spectacles for himself against he grows old: for which spectacles he has no want or use whatever at the time he makes them. Could this be done without knowing and considering the defect of vision to which advanced age is subject? Would not the precise suitableness of the instrument to its purpose, of the remedy to the defect, of the convex lens to the flattened eye, establish the certainty of the conclusion, that the case, afterwards to arise, had been considered beforehand, speculated upon, provided for? all which are exclusively the acts of a reasoning mind. The eye formed in one state, for use only in another state, and in a different state, affords a proof no less clear of destination to a future purpose; and a proof proportionably stronger, as the machinery is more complicated, and the adaptation more exact.

IV. What has been said of the eye, holds equally true of the *lungs*. Composed of air vessels, where there is no air; elaborately constructed for the alternate admission and exclusion of an elastic fluid, where no such fluid exists; this great organ, with the whole apparatus belonging to it, lies collapsed in the fœtal thorax, yet in order, and in readiness for action, the first moment that the occasion requires its service. This is having a machine locked up in store for a future use; which incontestibly proves, that the case was expected to occur, in which this use might be experienced; but expectation is the proper act of intelligence. Considering the state in which an animal exists *before* its birth, I should look for nothing less in its

body than a system of lungs. It is like finding a pair of bellows in the bottom of the sea; of no sort of use in the situation in which they are found; formed for an action which was impossible to be exerted; holding no relation or fitness to the element which surrounds them, but both to another element in another place.

As part and parcel of the same plan ought to be mentioned, in speaking of the lungs, the provisionary contrivances of the foramen ovale and ductus arteriosus. In the fœtus, pipes are laid for the passage of the blood through the lungs; but, until the lungs be inflated by the inspiration of air, that passage is impervious, or in a great degree obstructed. What then is to be done? What would an artist, what would a master do upon the occasion? He would endeavour, most probably, to provide a *temporary* passage, which might carry on the communication required, until the other was open. Now this is the thing, which is, actually, done in the heart. Instead of the circuitous rout through the lungs, which the blood afterwards takes, before it get from one auricle of the heart to the other; a portion of the blood passes immediately from the right auricle to the left, through a hole, placed in the partition, which separates these cavities. This hole anatomists call the *foramen ovale*. There is likewise another cross cut, answering the same purpose, by what is called the *ductus arteriosus*, lying between the pulmonary artery and the aorta. But both expedients are so strictly temporary, that, after birth, the one passage is closed, and the tube which forms the other shrivelled up into a ligament. If this be not contrivance, what is?

But, forasmuch as the action of the air upon the blood in the lungs, appears to be necessary to the perfect concoction of that fluid, i. e. to the life and health of the animal, (otherwise the shortest rout might still be the best,)

how comes it to pass that the fœtus lives, and grows, and thrives, without it? The answer is, that the blood of the fœtus is the mother's; that it has undergone that action in her habit; that one pair of lungs serves for both. When the animals are separated, a new necessity arises; and to meet this necessity as soon as it occurs, an organization is prepared. It is ready for its purpose: it only waits for the atmosphere: it begins to play, the moment the air is admitted to it.

CHAPTER XV.

RELATIONS.

WHEN several different parts contribute to one effect; or, which is the same thing, when an effect is produced by the joint action of different instruments; the fitness of such parts or instruments to one another, for the purpose of producing, by their united action, the effect, is what I call *relation:* and wherever this is observed in the works of nature or of man, it appears to me to carry along with it decisive evidence of understanding, intention, art. In examining, for instance, the several parts of a *watch* the spring, the barrel, the chain, the fusee, the balance, the wheels of various sizes, forms and positions, what is it which would take the observer's attention, as most plainly evincing a construction, directed by thought, deliberation, and contrivance? It is the suitableness of these parts to one another, first, in the succession and order in which they act; and, secondly, with a view to the effect finally produced. Thus, referring the spring to the wheels, he sees, in it, that which originates and upholds *their* mo-

tion; in the chain, that which transmits the motion to the fusee; in the fusee, that which communicates it to the wheels; in the conical figure of the fusee, if he refer back again to the spring, he sees that which corrects the inequality of its force. Referring the wheels to one another, he notices, first, their teeth, which would have been without use or meaning, if there had been only one wheel, or if the wheels had no connexion between themselves, or common bearing upon some joint effect; secondly, the correspondency of their position, so that the teeth of one wheel catch into the teeth of another; thirdly, the proportion observed in the number of teeth of each wheel, which determines the rate of going. Referring the balance to the rest of the works, he saw, when he came to understand its action, that which rendered their motions equable. Lastly, in looking upon the index and face of the watch, he saw the use and conclusion of the mechanism, viz. marking the succession of minutes and hours; but all depending upon the motions within, all upon the system of intermediate actions between the spring and the pointer. What thus struck his attention in the several parts of the watch he might probably designate by one general name of "relation:" and observing, with respect to all the cases whatever, in which the origin and formation of a thing could be ascertained by evidence, that these relations were found in things produced by art and design, and in no other things, he would rightly deem of them as characteristic of such productions. To apply the reasoning here described to the works of nature.

The animal economy is full; is made up of these *relations*.

I. There are first, what, in one form or other, belong to all animals, the parts and powers which successively act upon their *food*. Compare this action with the process of

a manufactury. In man and quadrupeds, the aliment is, first, broken and bruised by mechanical instruments of mastication, viz. sharp spikes or hard knobs, pressing against, or rubbing upon, one another: thus ground and comminuted, it is carried by a pipe into the stomach, where it waits to undergo a great chymical action, which we call digestion: when digested, it is delivered through an orifice, which opens and shuts as there is occasion, into the first intestine: there, after being mixed with certain proper ingredients, poured through a hole in the side of the vessel, it is further dissolved: in this state, the milk, chyle, or part which is wanted, and which is suited for animal nourishment, is strained off by the mouths of very small tubes, opening into the cavity of the intestines: thus freed from its grosser parts, the percolated fluid is carried by a long, winding, but traceable course, into the main stream of the old circulation; which conveys it, in its progress, to every part of the body. Now, I say again, compare this with the process of a manufactory; with the making of cider, for example, the bruising of the apples in the mill, the squeezing of them when so bruised in the press, the fermentation in the vat, the bestowing of the liquor thus fermented in the hogsheads, the drawing off into bottles, the pouring out for use into the glass. Let any one show me any difference between these two cases, as to the point of contrivance. That which is at present under our consideration, the "relation" of the parts successively employed, is not more clear in the last case, than in the first. The aptness of the jaws and teeth to prepare the food for the stomach, is, at least, as manifest, as that, of the cider-mill to crush the apples for the press. The concoction of the food in the stomach is as necessary for its future use, as the fermentation of the stum in the vat is to the perfection of the liquor. The disposal of the ali-

ment afterwards; the action and change which it undergoes; the rout which it is made to take, in order that, and until that, it arrive at its destination, is more complex indeed, and intricate; but, in the midst of complication and intricacy, as evident and certain, as is the apparatus of cocks, pipes, tunnels, for transferring the cider from one vessel to another, of barrels and bottles for preserving it till fit for use, or of cups and glasses for bringing it, when wanted, to the lip of the consumer. The character of the machinery is in both cases this, that one part answers to another part, and every part to the final result.

This parallel between the alimentary operation and some of the processes of art, might be carried further into detail. Spallanzani has remarked* a circumstantial resemblance between the stomachs of gallinaceous fowls and the structure of *corn-mills*. Whilst the two sides of the gizzard perform the office of the mill-stones, the craw or crop supplies the place of the hopper. When our fowls are abundantly supplied with meat they soon fill their craw; but it does not immediately pass thence into the gizzard. It always enters in very small quantities, in proportion to the progress of trituration: in like manner as in a mill a receiver is fixed above the two large stones which serve for grinding the corn; which receiver, although the corn be put into it by bushels, allows the grain to dribble only in small quantities into the central hole in the upper mill-stone.

But we have not done with the alimentary history. There subsists a general *relation* between the external organs of an animal by which it procures its food, and the internal powers by which it digests it. Birds of prey, by their talons and beaks, are qualified to seize and devour

* Diss. I. sec. liv.

many species, both of other birds, and of quadrupeds. The constitution of the stomach agrees exactly with the form of the members. The gastric juice of a bird of prey, of an owl, a falcon, or a kite, acts upon the animal fibre alone; will not act upon seeds or grasses at all. On the other hand, the conformation of the mouth of the sheep or the ox is suited for browsing upon herbage. Nothing about these animals is fitted for the pursuit of living prey. Accordingly it has been found by experiments, tried not many years ago with perforated balls, that the gastric juice of ruminating animals, such as the sheep and the ox, speedily dissolves vegetables, but makes no impression upon animal bodies. This accordancy is still more particular. The gastric juice even of graminivorous birds, will not act upon the grain, whilst whole and entire. In performing the experiment of digestion with the gastric juice in vessels, the grain must be crushed and bruised, before it be submitted to the menstruum, that is to say, must undergo by art, without the body, the preparatory action which the gizzard exerts upon it within the body, or no digestion will take place. So strict is the relation between the offices assigned to the digestive organ; between the mechanical operation, and the chymical process.

II. The relation of the kidneys to the bladder, and of the uterus to both, i. e. of the secreting organ to the vessel receiving the secreted liquor, and the pipe laid from one to the other for the purpose of conveying it from one to the other, is as manifest as it is amongst the different vessels employed in a distillery, or in the communications between them. The animal structure, in this case, being simple, and the parts easily separated, it forms an instance of correlation which may be presented by dissection to every eye, or which, indeed, without dissection, is capable of being apprehended by every understanding.

This correlation of instruments to one another fixes intention somewhere.

Especially when every other solution is negatived by the conformation. If the bladder had been merely an expansion of the ureter, produced by retention of the fluid, there ought to have been a bladder for each ureter. One receptacle, fed by two pipes, issuing from different sides of the body, yet from both conveying the same fluid, is not to be accounted for by any such supposition as this.

III. Relation of parts to one another accompanies us throughout the whole animal economy. Can any relation be more simple, yet more convincing, than this, that the eyes are so placed as to look in the direction in which the legs move and the hands work? It might have happened very differently, if it had been left to chance. There were, at least, three quarters of the compass out of four to have erred in. Any considerable alteration in the position of the eye, or the figure of the joints, would have disturbed the line, and destroyed the alliance between the sense and the limbs.

IV. But relation perhaps is never so striking, as when it subsists, not between different parts of the same thing, but between different things. The relation between a lock and a key is more obvious, than it is between different parts of the lock. A bow was designed for an arrow, and an arrow for a bow; and the design is more evident for their being separate implements.

Nor do the works of the Deity want this clearest species of relation. The *sexes* are manifestly made for each other. They form the grand relation of animated nature; universal, organic, mechanical; subsisting, like the clearest relations of art, in different individuals; unequivocal, inexplicable, without design:—So much so, that, were every other proof of contrivance in nature dubious or obscur

this alone would be sufficient. The example is complete. Nothing is wanting to the argument. I see no way whatever of getting over it.

V. The teats of animals, which give suck, bear a relation to the mouth of the suckling progeny; particularly to the lips and tongue. Here also, as before, is a correspondency of parts; which parts subsist in different individuals.

These are *general* relations, or the relations of parts which are found, either in all animals, or in large classes and descriptions of animals. *Particular* relations, or the relations which subsist between the particular configuration of one or more parts of certain species of animals, and the particular configuration of one or more other parts of the same animal, (which is the sort of relation, that is, perhaps, most striking,) are such as the following.

I. In the *swan;* the web foot, the spoon bill, the long neck, the thick down, the graminivorous stomach, bear all a relation to one another, inasmuch as they all concur in one design, that of supplying the occasions of an aquatic fowl, floating upon the surface of shallow pools of water, and seeking its food at the bottom. Begin with any one of these particularities of structure, and observe how the rest follow it. The web foot qualifies the bird for swimming; the spoon bill enables it to graze. But how is an animal, floating upon the surface of pools of water, to graze at the bottom, except by the mediation of a long neck? A long neck accordingly is given to it. Again, a warm blooded animal, which was to pass its life upon water, required a defence against the coldness of that element. Such a defence is furnished to the swan, in the muff in which its body is wrapped. But all this outward apparatus would have been in vain, if the intestinal system had not been suited to the digestion of vegetable sub-

stances. I say suited to the digestion of vegetable substances: for it is well known, that there are two intestinal systems found in birds, one with a membranous stomach and a gastric juice, capable of dissolving animal substances alone; the other with a crop and gizzard, calculated for the moistening, bruising, and afterwards digesting, of vegetable aliment.

Or set off with any other distinctive part in the body of the swan; for instance, with the long neck. The long neck, without the web foot, would have been an incumbrance to the bird; yet there is no necessary connexion between a long neck and a web foot. In fact they do not usually go together. How happens it, therefore, that they meet only when a particular design demands the aid of both?

II. This mutual relation, arising from a subserviency to a common purpose, is very observable also in the parts of a *mole*. The strong short legs of that animal, the palmated feet, armed with sharp nails, the pig-like nose, the teeth, the velvet coat, the small external ear, the sagacious smell, the sunk protected eye, all conduce to the utilities, or to the safety, of its underground life. It is a special purpose, specially consulted throughout. The form of the feet fixes the character of the animal. They are so many shovels: they determine its action to that of rooting in the ground; and every thing about its body agrees with this destination. The cylindrical figure of the mole, as well as the compactness of its form, arising from the terseness of its limbs, proportionally lessens its labour; because, according to its bulk, it thereby requires the least possible quantity of earth to be removed for its progress. It has nearly the same structure of the face and jaws as a swine, and the same office for them. The nose is sharp,

slender, tendinous, strong; with a pair of nerves going down to the end of it. The plush covering, which, by the smoothness, closeness, and polish of the short piles that compose it, rejects the adhesion of almost every species of earth, defends the animal from cold and wet, and from the impediment, which it would experience by the mould sticking to its body. From soils of all kinds, the little pioneer comes forth bright and clean. Inhabiting dirt, it is, of all animals, the neatest.

But what I have always most admired in the mole is its *eyes*. This animal occasionally visiting the surface, and wanting, for its safety and direction, to be informed when it does so, or when it approaches it, a perception of light was necessary. I do not know that the clearness of sight depends at all upon the size of the organ. What is gained by the largeness or prominence of the globe of the eye is width in the field of vision. Such a capacity would be of no use to an animal which was to seek its food in the dark. The mole did not want to look about it: nor would a large advanced eye have been easily defended from the annoyance, to which the life of the animal must constantly expose it. How indeed was the mole, working its way under ground, to guard its eyes at all? In order to meet this difficulty, the eyes are made scarcely larger than the head of a corking pin; and these minute globules are sunk so deep in the skull, and lie so sheltered within the velvet of its covering, as that any contraction of what may be called the eyebrows, not only closes up the apertures which lead to the eyes, but presents a cushion, as it were, to any sharp or protruding substance, which might push against them. This aperture even in its ordinary state is like a pin hole in a piece of velvet, scarcely pervious to loose particles of earth.

Observe then, in this structure, that which we call re-

lation. There is no natural connexion between a small sunk eye and a shovel palmated foot. Palmated feet might have been joined with goggle eyes; or small eyes might have been joined with feet of any other form. What was it therefore which brought them together in the mole? That which brought together the barrel, the chain, and the fusee, in a watch: design; and design, in both cases, inferred, from the relation which the parts bear to one another in the prosecution of a common purpose. As hath already been observed, there are different ways of stating the relation, according as we set out from a different part. In the instance before us, we may either consider the shape of the feet, as qualifying the animal for that mode of life and inhabitation, to which the structure of its eye confines it; or we may consider the structure of the eye, as the only one which would have suited with the action to which the feet are adapted. The relation is manifest, whichever of the parts related we place first in the order of our consideration. In a word: the feet of the mole are made for digging; the neck, nose, eyes, ears and skin, are peculiarly adapted to an underground life: and this is what I call relation.

CHAPTER XVI.

COMPENSATION.

COMPENSATION is a species of relation. It is relation, when the *defects* of one part, or of one organ, are supplied by the structure of another part, or of another organ. Thus,

I. The short, unbending neck of the *elephant*, is com-

pensated by the length and flexibility of his *proboscis*. He could not have reached the ground without it: or, if it be supposed that he might have fed upon the fruit, leaves, or branches of trees, how was he to drink? Should it be asked, why is the elephant's neck so short? it may be answered that the weight of a head so heavy could not have been supported at the end of a longer lever. To a form therefore, in some respects necessary, but in some respects also inadequate to the occasions of the animal, a supplement is added, which exactly makes up the deficiency under which he laboured.

If it be suggested, that this proboscis may have been produced in a long course of generations, by the constant endeavour of the elephant to thrust out his nose, (which is the general hypothesis by which it has lately been attempted to account for the forms of animated nature,) I would ask, how was the animal to subsist in the mean time, during the process; *until* this prolongation of snout were completed? What was to become of the individual, whilst the species was perfecting?

Our business at present is, simply to point out the relation, which this organ bears to the peculiar figure of the animal, to which it belongs. And, herein, all things correspond. The necessity of the elephant's proboscis arises from the shortness of his neck; the shortness of the neck is rendered necessary by the weight of the head. Were we to enter into an examination of the structure and anatomy of the proboscis itself, we should see in it one of the most curious of all examples of animal mechanism. The disposition of the ringlets and fibres, for the purpose, first, of forming a long cartilaginous pipe; secondly, of contracting and lengthening the pipe; thirdly, of turning it in every direction at the will of the animal; with the superaddition, at the end, of a fleshy production, of about

the length and thickness of a finger, and performing the office of a finger, so as to pick up a straw from the ground; these properties of the same organ, taken together, exhibit a specimen, not only of design, (which is attested by the advantage,) but of consummate art, and, as I may say, of elaborate preparation, in accomplishing that design.

II. The hook in the wing of a *bat*, is strictly a mechanical, and, also, a *compensating* contrivance. At the angle of its wing there is a bent claw, exactly in the form of a hook, by which the bat attaches itself to the sides of rocks, caves, and buildings, lying hold of crevices, joinings, chinks, and roughnesses. It hooks itself by this claw; remains suspended by this hold; takes its flight from this position: which operations compensate for the decrepitude of its legs and feet. Without her hook, the bat would be the most helpless of all animals. She can neither run upon her feet, nor raise herself from the ground. These inabilities are made up to her by the contrivance in her wing: and in placing a claw on that part, the Creator has deviated from the analogy observed in winged animals. A singular defect required a singular substitute.

III. The *crane* kind are to live and seek their food amongst the waters; yet, having no web feet, are incapable of swimming. To make up for this deficiency, they are furnished with long legs for wading, or long bills for groping; or usually with both. This is *compensation*. But I think the true reflection upon the present instance is, how every part of nature is tenanted by appropriate inhabitants. Not only is the surface of deep waters peopled by numerous tribes of birds that swim, but marshes and shallow pools are furnished with hardly less numerous tribes of birds that wade.

IV. The common *parrot* has, in the structure of it

beak, both an inconveniency, and a *compensation* for it. When I speak of an inconveniency, I have a view to a dilemma which frequently occurs in the works of nature, viz. that the peculiarity of structure by which an organ is made to answer one purpose, necessarily unfits it for some other purpose. This is the case before us. The upper bill of a parrot is so much hooked, and so much overlaps the lower, that, if, as in other birds, the lower chap alone had motion, the bird could scarcely gape wide enough to receive its food: yet this hook and overlapping of the bill could not be spared, for it forms the very instrument by which the bird climbs: to say nothing of the use which it makes of it in breaking nuts, and the hard substances upon which it feeds. How, therefore, has nature provided for the opening of this occluded mouth? By making the upper chap moveable, as well as the lower. In most birds, the upper chap is connected, and makes but one piece with the skull; but, in the parrot, the upper chap is joined to the bone of the head by a strong membrane, placed on each side of it, which lifts and depresses it at pleasure.*

V. The *spider's web* is a *compensating* contrivance. The spider lives upon flies, without wings to pursue them; a case, one would have thought, of great difficulty; yet provided for; and provided for by a resource, which no stratagem, no effort of the animal, could have produced, had not both its external and internal structure been specifically adapted to the operation.

VI. In many species of insects the eye is fixed; and consequently without the power of turning the pupil to the object. This great defect is however perfectly *compensated;* and by a mechanism which we should not suspect. The eye is a multiplying glass; with a lens looking in

* Goldsmith's Nat. Hist. vol. v. p. 274.

every direction, and catching every object. By which means, although the orb of the eye be stationary, the field of vision is as ample as that of other animals; and is commanded on every side. When this lattice work was first observed, the multiplicity and minuteness of the surfaces must have added to the surprise of the discovery. Adams tells us, that fourteen hundred of these reticulations have been counted in the two eyes of a drone bee.

In other cases, the *compensation* is effected by the number and position of the eyes themselves. The spider has eight eyes, mounted upon different parts of the head, two in front, two in the top of the head, two on each side. These eyes are without motion; but, by their situation, suited to comprehend every view, which the wants or safety of the animal render it necessary for it to take.

VII. The memoirs for the Natural History of Animals, published by the French Academy, A. D. 1687, furnish us with some curious particulars in the eye of a camelion. Instead of two eyelids, it is covered by an eyelid with a hole in it. This singular structure appears to be a *compensatory*, and to answer to some other singularities in the shape of the animal. The neck of the camelion is inflexible. To make up for this, the eye is so prominent, as that more than half of the ball stands out of the head. By means of which extraordinary projection, the pupil of the eye can be carried by the muscles in every direction, and is capable of being pointed towards every object. But, then, so unusual an exposure of the globe of the eye, requires, for its lubricity and defence, a more than ordinary protection of eyelid, as well as more than ordinary supply of moisture; yet the motion of an eyelid, formed according to the common construction, would be impeded, as it should seem, by the convexity of the organ. The aperture in the lid meets this difficulty. It enables the animal to

keep the principal part of the surface of the eye under cover, and to preserve it in a due state of humidity, without shutting out the light; or without performing every moment a nictitation, which, it is probable, would be more laborious to this animal than to others.

VIII. In another animal, and in another part of the animal economy, the same Memoirs describe a most remarkable *substitution*. The reader will remember what we have already observed concerning the *intestinal* canal; that its length, so many times exceeding that of the body, promotes the extraction of the chyle from the aliment, by giving room for the lacteal vessels to act upon it through a greater space. This long intestine, wherever it occurs, is, in other animals, disposed in the abdomen from side to side in returning folds. But, in the animal now under our notice, the matter is managed otherwise. The same intention is mechanically effectuated; but by a mechanism of a different kind. The animal of which I speak, is an amphibious quadruped, which our authors call the alopecias, or sea fox. The intestine is straight from one end to the other: but in this straight, and consequently short intestine, is a winding, cork-screw, spiral passage, through which, the food, not without several circumvolutions, and in fact by a long rout, is conducted to its exit. Here the shortness of the gut is *compensated* by the obliquity of the perforation.

IX. But the works of the Deity are known by expedients. Where we should look for absolute destitution; where we can reckon up nothing but wants; some contrivance always comes in to supply the privation. A *snail*, without wings, feet, or thread, climbs up the stalks of plants, by the sole aid of a viscid humour discharged from her skin. She adheres to the stems, leaves, and fruits of plants, by means of a sticking plaister. A *muscle*, which

might seem, by its helplessness, to lie at the mercy of every wave that went over it, has the singular power of spinning, strong, tendinous threads, by which she moors her shell to rocks and timbers. A *cockle*, on the contrary, by means of its stiff tongue, works for itself a shelter in the sand. The provisions of nature extend to cases the most desperate. A *lobster* has a difficulty, in its constitution so great, that one could hardly conjecture beforehand how nature would dispose of it. In most animals, the skin grows with their growth. If, instead of a soft skin, there be a shell, still it admits of a gradual enlargement. If the shell, as in the tortoise, consist of several pieces, the accession of substance is made at the sutures. Bivalve shells grow bigger by receiving an accretion at their edge: it is the same with spiral shells at their mouth. The simplicity of their form admits of this. But the lobster's shell being applied to the limbs of the body, as well as to the body itself, allows not of either of the modes of growth which are observed to take place in other shells. Its hardness resists expansion; and its complexity renders it incapable of increasing its size by addition of substance to its edge. How then was the growth of the lobster to be provided for? Was room to be made for it in the old shell, or was it to be successively fitted with new ones? If a change of shell became necessary, how was the lobster to extricate himself from his present confinement? How was he to uncase his buckler, or draw his legs out of his boots? The process, which fishermen have observed to take place, is as follows. At certain seasons, the shell of a lobster grows soft; the animal swells its body; the seams open, and the claws burst at the joints. When the shell is thus become loose upon the body, the animal makes a second effort, and by a tremulous spasmodic mo-

tion, casts it off. In this state the liberated, but defenceless fish, retires into holes in the rock. The released body now suddenly pushes its growth. In about eight-and-forty hours, a fresh concretion of humour upon the surface, i. e. a new shell, is formed, adapted in every part to the increased dimensions of the animal. This wonderful mutation is repeated every year.

If there be imputed defects without compensation, I should suspect that they were defects only in appearance. Thus, the body of the *sloth* has often been reproached for the slowness of its motions, which has been attributed to an imperfection in the formation of its limbs. But it ought to be observed, that it is this slowness, which alone suspends the voracity of the animal. He fasts during his migration from one tree to another; and this fast may be necessary for the relief of his over-charged vessels, as well as to allow time for the concoction of the mass of coarse and hard food which he has taken into his stomach. The tardiness of his pace seems to have reference to the capacity of his organs, and to his propensities with respect to food, i. e. is calculated to counteract the effects of repletion.

Or there may be cases, in which a defect is artificial, and compensated by the very cause which produces it. Thus the *sheep*, in the domesticated state in which we see it, is destitute of the ordinary means of defence or escape; is incapable either of resistance or flight. But this is not so with the wild animal. The natural sheep is swift and active: and, if it lose these qualities when it comes under the subjection of man, the loss is compensated by his protection. Perhaps there is no species of quadruped whatever, which suffers so little as this does, from the depredation of animals of prey.

For the sake of making our meaning better understood,

we have considered this business of compensation under certain *particularities* of constitution, in which it appears to be most conspicuous. This view of the subject necessarily limits the instances to single species of animals. But there are compensations, perhaps, not less certain, which extend over large classes, and to large portions of living nature.

I. In quadrupeds, the deficiency of teeth is usually *compensated* by the faculty of rumination. The sheep, deer, and ox tribe, are without fore-teeth in the upper jaw. These ruminate. The horse and ass are furnished with teeth in the upper jaw, and do not ruminate. In the former class the grass and hay descend into the stomach, nearly in the state in which they are cropped from the pasture, or gathered from the bundle. In the stomach they are softened by the gastric juice, which in these animals is unusually copious. Thus softened, and rendered tender, they are returned a second time to the action of the mouth, where the grinding teeth complete at their leisure the trituration which is necessary, but which was before left imperfect. I say the trituration which is necessary; for it appears from experiments that the gastric fluid of sheep, for example, has no effect in digesting plants, unless they have been previously masticated; that it only produces a slight maceration, nearly as common water would do in a like degree of heat: but that, when once vegetables are reduced to pieces by mastication, the fluid then exerts upon them its specific operation. Its first effect is to soften them, and to destroy their natural consistency: it then goes on to dissolve them; not sparing even the toughest parts, such as the nerves of the leaves.*

I think it very probable that the gratification also of the animal is renewed and prolonged, by this faculty.

* Spal. Dis. III. sec. cxl.

Sheep, deer, and oxen, appear to be in a state of enjoyment whilst they are chewing the cud. It is then, perhaps, that they best relish their food.

II. In birds, the *compensation* is still more striking. They have no teeth at all. What have they then to make up for this severe want? I speak of graminivorous and herbivorous birds; such as common fowls, turkeys, ducks, geese, pidgeons, &c. for it is concerning these alone that the question need be asked. All these are furnished with a peculiar and most powerful muscle, called the *gizzard;* the inner coat of which is fitted up with rough plaits, which, by a strong friction against one another, break and grind the hard aliment as effectually, and by the same mechanical action, as a coffee-mill would do. It has been proved by the most correct experiments, that the gastric juice of these birds will not operate upon the *entire* grain; not even when softened by water or macerated in the crop. Therefore without a grinding machine within its body; without the trituration of the gizzard; a chicken would have starved upon a heap of corn. Yet why should a bill and a gizzard go together? Why should a gizzard never be found where there are teeth?

Nor does the gizzard belong to birds as such. A gizzard is not found in birds of prey. *Their* food requires not to be ground down in a mill. The compensatory contrivance goes no further than the necessity. In both classes of birds, however, the digestive organ within the body, bears a strict and mechanical relation to the external instruments for procuring food. The soft membranous stomach, accompanies the hooked, notched, beak; the short, muscular legs; the strong, sharp, crooked talons: the cartiliginous stomach, attends that conformation of bill and toes, which restrains the bird to the picking of seeds or the cropping of plants.

III. But to proceed with our *compensations*. A very numerous and comprehensive tribe of terrestrial animals are entirely without feet; yet locomotive; and, in a very considerable degree, swift in their motion. How is the *want of feet* compensated? It is done by the disposition of the muscles and fibres of the trunk. In consequence of the just collocation, and by means of the joint action of longitudinal and annular fibres, that is to say, of strings and rings, the body and train of reptiles are capable of being reciprocally shortened and lengthened, drawn up and stretched out. The result of this action is a progressive, and, in some cases, a rapid movement of the whole body, in any direction to which the will of the animal determines it. The meanest creature is a collection of wonders. The play of the rings in an *earth-worm*, as it crawls; the undulatory motion propagated along the body; the beards or prickles, with which the annuli are armed, and which the animal can either shut up close to its body, or let out to lay hold of the roughnesses of the surface upon which it creeps; and, the power arising from all these, of changing its place and position, affords, when compared with the provisions for motion in other animals, proofs of new and appropriate mechanism. Suppose that we had never seen an animal move upon the ground without feet, and that the problem was, muscular action, i. e. reciprocal contraction and relaxation being given, to describe how such an animal might be constructed, capable of voluntarily changing place. Something, perhaps, like the organization of reptiles, might have been hit upon by the ingenuity of an artist; or might have been exhibited in an automaton, by the combination of springs, spiral wires, and ringlets: but to the solution of the problem would not be

denied, surely, the praise of invention and of successful thought; least of all could it ever be questioned, whether intelligence had been employed about it, or not.

CHAPTER XVII.

THE RELATION OF ANIMATED BODIES TO INANIMATE NATURE.

WE have already considered *relation*, and under different views; but it was the relation of parts to parts, of the parts of an animal to other parts of the same animal, or of another individual of the same species.

But the bodies of animals, hold, in their constitution and properties, a close and important relation to natures altogether external to their own; to inanimate subtances, and to the specific qualities of these, e. g. *they hold a strict relation to the elements by which they are surrounded.*

I. Can it be doubted, whether the *wings of birds* bear a relation to air, and the *fins of fish* to water? They are instruments of motion, severally suited to the properties of the medium by which the motion is to be performed: which properties are different. Was not this difference contemplated, when the instruments were differently constituted?

II. The structure of the animal *ear* depends for its use not simply upon being surrounded by a fluid, but upon the specific nature of that fluid. Every fluid would not serve: its particles must repel one another; it must form an elastic medium: for it is by the successive pulses of *such* a medium, that the undulations excited by the sound-

ing body are carried to the organ; that a communication is formed between the object and the sense; which must be done before the internal machinery of the ear, subtile as it is, can act at all.

III. The *organs* of speech, and voice, and respiration, are, no less than the ear, indebted for the success of their operation, to the peculiar qualities of the fluid, in which the animal is immersed. They, therefore, as well as the ear, are constituted upon the supposition of such fluid, i. e. of a fluid with such particular properties, being always present. Change the properties of the fluid, and the organ cannot act: change the organ, and the properties of the fluid would be lost. The structure therefore of our organs, and the properties of our atmosphere, are made for one another. Nor does it alter the relation, whether you allege the organ to be made for the element, (which seems the most natural way of considering it,) or the element as prepared for the organ.

IV. But there is another fluid with which we have to do; with properties of its own; with laws of acting, and of being acted upon, totally different from those of air or water:—and that is *light*. To this new, this singular element; to qualities perfectly peculiar, perfectly distinct and remote from the qualities of any other substance with which we are acquainted, an organ is adapted, an instrument is correctly adjusted, not less peculiar amongst the parts of the body, not less singular in its form, and, in the substance of which it is composed, not less remote from the materials, the model, and the analogy of any other part of the animal frame, than the element to which it relates, is specific amidst the substances with which we converse. If this does not prove appropriation, I desire to know what would prove it.

Yet the element of light and the organ of vision, how-

ever related in their office and use, have no connexion whatever in their original. The action of rays of light upon the surfaces of animals has no tendency to breed eyes in their heads. The sun might shine for ever upon living bodies without the smallest approach towards producing the sense of sight. On the other hand also, the animal eye does *not* generate or emit light.

V. Throughout the universe there is a wonderful *proportioning* of one thing to another. The size of animals, of the human animal especially, when considered with respect to other animals, or to the plants which grow around him, is such, as a regard to his conveniency would have pointed out. A giant or pigmy could not have milked goats, reaped corn, or mowed grass; we may add, could not have rode a horse, trained a vine, shorn a sheep, with the same bodily ease as we do, if at all. A pigmy would have been lost amongst rushes, or carried off by birds of prey.

It may be mentioned likewise, that, the model and the materials of the human body being what they are, a much greater bulk would have broken down by its own weight. The persons of men, who much exceed the ordinary stature, betray this tendency.

VI. Again: and which includes a vast variety of particulars, and those of the greatest importance, how close is the *suitableness* of the earth and sea to their several inhabitants; and of these inhabitants to the places of their appointed residence?

Take the *earth* as it is; and consider the correspondency of the powers of its inhabitants with the properties and condition of the soil which they tread. Take the inhabitants as they are; and consider the substances which the earth yields for their use. They can scratch its surface, and its surface supplies all which they want. This

is the length of their faculties; and such is the constitution of the globe, and their own, that this is sufficient for all their occasions.

When we pass from the earth to the *sea*, from land to water, we pass through a great change; but an adequate change accompanies us of animal forms and functions of animal capacities and wants so that *correspondency* remains. The earth in its nature is very different from the sea, and the sea from the earth; but one accords with its inhabitants, as exactly as the other.

VII. The last relation of this kind which I shall mention is that of *sleep* to *night*. And it appears to me to be a relation which was expressly intended. Two points are manifest: first, that the animal frame requires sleep; secondly, that night brings with it a silence, and a cessation of activity, which allows of sleep being taken without interruption, and without loss. Animal existence is made up of action and slumber: nature has provided a season for each. An animal, which stood not in need of rest, would always live in daylight. An animal, which, though made for action, and delighting in action, must have its strength repaired by sleep, meets by its constitution the returns of day and night. In the human species, for instance, where the bustle, the labour, the motion of life, upheld by the constant presence of light, sleep could not be enjoyed without being disturbed by noise, and without expense of that time, which the eagerness of private interest would not contentedly resign. It is happy therefore for this part of the creation, I mean that it is conformable to the frame and wants of their constitution, that nature, by the very disposition of her elements, has commanded, as it were, and imposed upon them, at moderate intervals, a general intermission of their toils, their occupations, and pursuits.

But it is not for man, either solely or principally, that night is made. Inferior, but less perverted natures, taste its solace, and expect its return, with greater exactness and advantage than he does. I have often observed, and never observed but to admire, the satisfaction, no less than the regularity, with which the greatest part of the irrational world yield to this soft necessity, this grateful vicissitude; how comfortably the birds of the air, for example, address themselves to the repose of the evening; with what alertness they resume the activity of the day.

Nor does it disturb our argument to confess, that certain species of animals are in motion during the night, and at rest in the day. With respect even to them it is still true, that there is a change of condition in the animal, and an external change corresponding with it. There is still the relation, though inverted. The fact is, that the repose of other animals sets these at liberty, and invites them to their food or their sport.

If the relation of *sleep* to *night*, and in some instances, its converse, be real, we cannot reflect without amazement upon the extent to which it carries us. Day and night are things close to us: the change applies immediately to our sensations: of all the phenomena of nature, it is the most familiar to our experience: but in its cause, it belongs to the great motions which are passing in the heavens. Whilst the earth glides round her axle, she ministers to the alternate necessities of the animals dwelling upon her surface, at the same time that she obeys the influence of those attractions, which regulate the order of many thousand worlds. The relation therefore of sleep to night, is the relation of the inhabitants of the earth to the rotation of their globe; probably it is more: it is a relation to the system, of which that globe is a part; and,

still further, to the congregation of systems, of which theirs is only one. If this account be true, it connects the meanest individual with the universe itself; a chicken roosting upon its perch, with the spheres revolving in the firmament.

But if any one object to our representation, that the succession of day and night, or the rotation of the earth upon which it depends, is not resolvable into central attraction, we will refer him to that which certainly is—to the change of the seasons. Now the constitution of animals susceptible of torpor, bears a relation to winter, similar to that which sleep bears to night. Against not only the cold, but the want of food, which the approach of winter induces, the preserver of the world has provided, in many animals by migration, in many others by torpor. As one example out of a thousand, the bat, if it did not sleep through the winter, must have starved, as the moths and flying insects, upon which it feeds, disappear. But the transition from summer to winter, carries us into the very midst of physical astronomy, that is to say, into the midst of those laws which govern the solar system at least, and probably all the heavenly bodies.

CHAPTER XVIII.

INSTINCTS.

THE order may not be very obvious, by which I place *instincts* next to relations. But I consider them as a species of relation. They contribute, along with the animal organization, to a joint effect, in which view they are related to that organization. In many cases they refer from one animal to another animal: and when this is

the case, become strictly relations in a second point of view.

An intinct is a propensity prior to experience, and independent of instruction. We contend, that it is by instinct that the sexes of animals seek each other; that animals cherish their offspring; that the young quadruped is directed to the teat of its dam; that birds build their nests and brood with so much patience upon their eggs; that insects which do not sit upon their eggs, deposit them in those particular situations, in which the young, when hatched, find their appropriate food; that it is instinct, which carries the salmon, and some other fish, out of the sea into rivers, for the purpose of shedding their spawn in fresh water.

We may select out of *this* catalogue the incubation of eggs. I entertain no doubt, but that a couple of sparrows hatched in an oven, and kept separate from the rest of their species, would proceed as other sparrows do, in every office which related to the production and preservation of their brood. Assuming this fact, the thing is inexplicable upon any other hypothesis, than that of an instinct, impressed upon the constitution of the animal. For, first, what should induce the female bird to prepare a nest before she lays her eggs? It is in vain to suppose her to be possessed of the faculty of reasoning; for no reasoning will reach the case. The fullness or distention which she might feel in a particular part of her body, from the growth and solidity of the egg within her, could not possibly inform her, that she was about to produce something, which, when produced, was to be preserved and taken care of. Prior to experience, there was nothing to lead to this inference, or to this suspicion. The analogy was *all* against it: for, in every other instance, what issued from the body was cast out and rejected.

But, secondly, let us suppose the egg to be produced into day: how should birds know that their eggs contain their young; there is nothing either in the aspect, or in the internal composition of an egg, which could lead even the most daring imagination to a conjecture, that it was hereafter to turn out, from under its shell, a living, perfect bird. The form of the egg bears not the rudiments of a resemblance to that of the bird. Inspecting its contents, we find still less reason, if possible, to look for the result which actually takes place. If we should go so far, as, from the appearance of order and distinction in the disposition of the liquid substances which we noticed in the egg, to guess that it might be designed for the abode and nutriment of an animal, (which would be a very bold hypothesis,) we should expect a tadpole dabbling in the slime, much rather than a dry, winged, feathered creature; a compound of parts and properties impossible to be used in a state of confinement in the egg, and bearing no conceivable relation, either in quality or material, to any thing observed in it. From the white of an egg, would any one look for the feathers of a goldfinch? or expect from a simple uniform mucilage, the most complicated of all machines, the most diversified of all collections of substances? nor would the process of incubation, for some time at least, lead us to suspect the event. Who that saw red streaks, shooting in the fine membrane which divides the white from the yolk, would suppose that these were about to become bones and limbs? Who, that espied two discoloured points first making their appearance in the cicatrix, would have had the courage to predict, that these points were to grow into the heart and head of a bird? It is difficult to strip the mind of its experience. It is difficult to resuscitate surprise, when familiarity has once laid

the sentiment asleep. But could we forget all that we know, and which *our* sparrows never knew, about oviparous generation; could we divest ourselves of every information, but what we derived from reasoning upon the appearances or quality discovered in the objects presented to us, I am convinced that Harlequin coming out of an egg upon the stage, is not more astonishing to a child, than the hatching of a chicken both would be, and ought to be, to a philosopher.

But admit the sparrow by some means to know, that within that egg was concealed the principle of a future bird, from what chymist was she to learn that *warmth* was necessary to bring it to maturity, or that the degree of warmth, imparted by the temperature of her own body, was the degree required?

To suppose, therefore, that the female bird acts in this process from a sagacity and reason of her own, is to suppose her to arrive at conclusions, which there are no premises to justify. If our sparrow, sitting upon her eggs, expect young sparrows to come out of them, she forms, I will venture to say, a wild and extravagant expectation, in opposition to present appearances, and to probability. She must have penetrated into the order of nature, further than any faculties of ours will carry us: and it hath been well observed, that this deep sagacity, if it be sagacity, subsists in conjunction with great stupidity, even in relation to the same subject. "A chymical operation," says Addison, "could not be followed with greater art or diligence, than is seen in hatching a chicken: yet is the process carried on without the least glimmering of thought or common sense. The hen will mistake a piece of chalk for an egg; is insensible of the increase or diminution of their number; does not distinguish between her own, and

those of another species; is frightened when her suppositions breed of ducklings take the water."

But it will be said, that what reason could not do for the bird, observation, or instruction, or tradition might. Now if it be true, that a couple of sparrows brought up from the first in a state of separation from all other birds, would build their nest, and brood upon their eggs, then there is an end of this solution. What can be the traditionary knowledge of a chicken hatched in an oven?

Of young birds taken in their nests, a few species breed, when kept in cages; and they which do so, build their nests nearly in the same manner as in the wild state, and sit upon their eggs. This is sufficient to prove an instinct, without having recourse to experiments upon birds, hatched by artificial heat, and deprived, from their birth, of all communication with their species: for we can hardly bring ourselves to believe, that the parent bird informed her unfledged pupil of the history of her gestation, her timely preparation of a nest, her exclusion of the eggs, her long incubation, and of the joyful eruption at last of her expected offspring: all which the bird in the cage must have learnt in her infancy, if we resolve her conduct into *institution*.

Unless we will rather suppose that she remembers her own escape from the egg; had attentively observed the conformation of the nest in which she was nurtured: and had treasured up her remarks for future imitation. Which is not only extremely improbable, (for who that sees a brood of callow birds in their nest, can believe that they are taking a plan of their habitation?) but leaves unaccounted for, one principal part of the difficulty, "the preparation of the nest before the laying of the egg." This she could not gain from observation in her infancy.

It is remarkable also, that the hen sits upon eggs which

she has laid without any communication with the male; and which are therefore necessarily unfruitful. That secret she is not let into. Yet, if incubation had been a subject of instruction or of tradition, it should seem that this distinction would have formed part of the lesson: whereas the instinct of nature is calculated for a state of nature; the exception, here alluded to, taking place, chiefly, if not solely, amongst domesticated fowls, in which nature is forced out of her course.

There is another case of oviparous economy, which is still less likely to be the effect of education, than it is even in birds, namely, that of *moths* and *butterflies*, which deposit their eggs in the precise substance, that of a cabbage for example, from which, not the butterfly herself, but the caterpillar which is to issue from her egg, draws its appropriate food. The butterfly cannot taste the cabbage. Cabbage is no food for her: yet in the cabbage, not by chance, but studiously and electively, she lays her egg. There are, amongst many other kinds, the willow caterpillar, and the cabbage caterpillar; but we never find upon a willow, the caterpillar which eats the cabbage; nor the reverse. This choice, as appears to me, cannot in the butterfly proceed from instruction. She had no teacher in her caterpillar state. She never knew her parent. I do not see, therefore, how knowledge, acquired by experience, if it ever were such, could be transmitted from one generation to another. There is no opportunity either for instruction or imitation. The parent race is gone before the new brood is hatched. And, if it be original reasoning in the butterfly, it is profound reasoning indeed. She must remember her caterpillar state, its tastes and habits; of which memory she shows no signs whatever. She must conclude from analogy, for here her recollection cannot serve her, that the little round body,

which drops from her abdomen, will at a future period produce a living creature, not like herself, but like the caterpillar, which she remembers herself once to have been. Under the influence of these reflections she goes about to make provision for an order of things, which, she concludes, will, some time or other, take place. And it is to be observed, that not a few out of many, but that all butterflies argue thus, all draw this conclusion, all act upon it.

But suppose the address, and the selection, and the plan, which we perceive in the preparations which many irrational animals make for their young, to be traced to some probable origin; still there is left to be accounted for, that which is the source and foundation of these phenomena, that which sets the whole at work, the STORGE, the parental affection, which I contend to be inexplicable upon any other hypothesis than that of instinct.

For we shall, hardly, I imagine, in brutes, refer their conduct towards their offspring to a sense of duty, or of decency, a care of reputation, a compliance with public manners, with public laws, or with rules of life built upon a long experience of their utility. And all attempts to account for the parental affection from association, I think, fail. With what is it associated? Most immediately with the throes of parturition, that is, with pain, and terror, and disease. The more remote, but not less strong association, that which depends upon analogy, is all against it. Every thing else, which proceeds from the body, is cast away and rejected.

In birds, is it the egg which the hen loves? or is it the expectation which she cherishes of a future progeny, that keeps her upon her nest? What cause has she to expect delight from her progeny? Can any rational answer

be given to the question, why, prior to experience, the brooding hen should look for pleasure from her chickens? It does not, I think, appear, that the cuckoo ever knows her young: yet, in her way, she is as careful in making provision for them, as any other bird. She does not leave her egg in every hole.

The salmon suffers no surmountable obstacle to oppose her progress up the stream of fresh rivers. And what does she do there? She sheds a spawn, which she immediately quits, in order to return to the sea; and this issue of her body she never afterwards recognises in any shape whatever. Where shall we find a motive for her efforts, and her perseverance? Shall we seek it in argumentation, or in instinct? The violet crab of Jamaica performs a fatiguing march of some months continuance, from the mountains to the sea side. When she reaches the coast, she casts her spawn into the open sea; and sets out upon her return home.

Moths and butterflies, as hath already been observed, seek out for their eggs, those precise situations and substances, in which the offspring caterpillar will find its appropriate food. That dear caterpillar, the parent butterfly, must never see. There are no experiments to prove that she would retain any knowledge of it, if she did. How shall we account for her conduct? I do not mean for her art and judgment in selecting and securing a maintenance for her young, but for the impulse upon which she acts. What should induce her to exert any art, or judgment, or choice, about the matter? The undisclosed grub, the animal, which she is destined not to know, can hardly be the object of a particular affection, if we deny the influence of instinct. There is nothing, therefore, left to her, but that, of which her nature seems incapable, an abstract anxiety for the general preservation of the species; a kind

of patriotism; a solicitude, lest the butterfly race should cease from the creation.

Lastly, the principle of association will not explain the discontinuance of the affection when the young animal is grown up. Association, operating in its usual way, would rather produce a contrary effect. The object would become more necessary by habits of society: whereas birds and beasts, after a certain time, banish their offspring; disown their acquaintance; seem to have even no knowledge of the objects which so lately engrossed the attention of their minds, and occupied the industry and labour of their bodies. This change, in different animals, takes place at different distances of time from the birth; but the time always corresponds with the ability of the young animal to maintain itself; never anticipates it. In the sparrow tribe, when it is perceived that the young brood can fly and shift for themselves, then the parents forsake them for ever; and, though they continue to live together, pay them no more attention than they do to other birds in the same flock.* I believe the same thing is true of all gregarious quadrupeds.

In this part of the case the variety of resources, expedients, and materials, which animals of the same species are said to have recourse to, under different circumstances and when differently supplied, makes nothing against the doctrine of instincts. The thing which we want to account for is the propensity. The propensity being there, it is probable enough that it may put the animal upon different actions according to different exigencies. And this adaptation of resources may look like the effect of art and consideration, rather than of instinct; but still the propensity is instinctive. For instance, suppose what is related of the wood-pecker to be true, that,

* Goldsmith's Nat. Hist. vol. iv. p. 244.

in Europe, she deposits her eggs in cavities, which she scoops out in the trunks of soft or decayed trees, and in which cavities the eggs lie concealed from the eye, and in some sort safe from the hand of man; but that, in the forests of Guinea and the Brasils, which man seldom frequents, the same bird hangs her nest to the twigs of tall trees; thereby placing them out of the reach of *monkeys* and *snakes*, i. e. that in each situation she prepares against the danger which she has most occasion to apprehend: suppose, I say, this to be true, and to be alleged, on the part of the bird that builds these nests, as evidence of a reasoning and distinguishing precaution, still the question returns, whence the propensity to build at all?

Nor does parental affection accompany generation by any universal law of animal organization, if such a thing were intelligible. Some animals cherish their progeny with the most ardent fondness, and the most assiduous attention; others entirely neglect them; and this distinction always meets the constitution of the young animal, with respect to its wants and capacities. In many, the parental care extends to the young animal; in others, as in all oviparous fish, it is confined to the egg, and even, as to that, to the disposal of it in its proper element. Also, as there is generation without parental affection, so is there parental instinct, or what exactly resembles it, without generation. In the bee tribe, the grub is nurtured neither by the father nor the mother, but by the neutral bee. Probably the case is the same with ants.

I am not ignorant of a theory, which resolves instinct into sensation; which asserts, that what appears to have a view and relation to the future, is the result only of the present disposition of the animal's body, and of pleasure or pain experienced *at the time*. Thus the incubation of eggs is accounted for by the pleasure which the bird is

supposed to receive from the pressure of the smooth convex surface of the shells against the abdomen, or by the relief, which the mild temperature of the egg may afford to the heat of the lower part of the body, which is observed at this time to be increased beyond its usual state. This present gratification is the only motive with the hen for sitting upon her nest: the hatching of the chickens is, with respect to her, an accidental consequence. The affection of viviparous animals for their young, is in like manner solved by the relief, and perhaps the pleasure, which they receive from giving suck. The young animal's seeking, in so many instances, the teat of its dam, is explained from the sense of smell, which is attracted by the odour of the milk. The salmon's urging its way up the stream of fresh water rivers, is attributed to some gratification or refreshment, which, in this particular state of the fish's body, she receives from the change of element. Now of this theory it may be said,

First, that, of the cases which require solution, there are few, to which it can be applied with tolerable probability:—that there are none, to which it can be applied without strong objections, furnished by the circumstances of the case. The attention of the cow to its calf, and of the ewe to its lamb, appear to be prior to their sucking. The attraction of the calf or lamb to the teat of the dam is not explained by simply referring it to the sense of smell. What made the scent of the milk so agreeable to the lamb that it should follow it up with its nose, or seek with its mouth the place from which it proceeded? No observation, no experience, no argument, could teach the new dropped animal, that the substance, from which the scent issued, was the material of its food. It had never tasted milk before its birth. None of the animals, which are not designed for that nourishment, ever offer to suck, or to se

out any such food. What is the conclusion, but that the sugescent parts of animals are fitted for their use, and the knowledge of that use put into them?

We assert, secondly, that, even as to the cases in which the hypothesis has the fairest claim to consideration, it does not at all lessen the force of the argument for intention and design. The doctrine of instincts, is that of appetencies, superadded to the constitution of an animal, for the effectuating of a purpose beneficial to the species. The above-stated solution would derive these appetencies from organization; but then this organization is not less specifically, not less precisely, and, therefore, not less evidently adapted to the same ends, than the appetencies themselves would be upon the old hypothesis. In this way of considering the subject, sensation supplies the place of foresight: but this is the effect of contrivance on the part of the Creator. Let it be allowed, for example, that the hen is induced to brood upon her eggs by the enjoyment or relief, which, in the heated state of her abdomen, she experiences from the pressure of round smooth surfaces, or from the application of a temperate warmth. How comes this extraordinary heat or itching, or call it what you will, which you suppose to be the cause of the bird's inclination, to be felt, just at the time when the inclination itself is wanted; when it tallies so exactly, with the internal constitution of the egg, and with the help which that constitution requires in order to bring it to maturity? In my opinion, this solution, if it be accepted as to the fact, ought to increase, rather than otherwise, our admiration of the contrivance. A gardener lighting up his stoves, just when he wants to force his fruit, and when his trees require the heat, gives not a more certain evidence of design. So again; when a male and female sparrow come together, they do not meet to confer upon

the expediency of perpetuating their species. As an abstract proposition, they care not the value of a barley corn whether the species be perpetuated, or not. They follow their sensations; and all those consequences ensue, which the wisest counsels could have dictated, which the most solicitous care of futurity, which the most anxious concern for the sparrow world, could have produced. But how do these consequences ensue? The sensations, and the constitution upon which they depend, are as manifestly directed to the purpose which we see fulfilled by them; and the train of intermediate effects, as manifestly laid and planned with a view to that purpose, that is to say, design is as complety evinced by the phenomena, as it would be, even if we suppose the operations to begin, or to be carried on, from what some will allow to be alone properly called instincts, that is, from desires directed to a future end, and having no accomplishment or gratification distinct from the attainment of that end.

In a word; I should say to the patrons of this opinion, Be it so: be it, that those actions of animals which we refer to instinct, are not gone about with any view to their consequences, but that they are attended in the animal with a present gratification, and are pursued for the sake of that gratification alone; what does all this prove, but that the *prospection*, which must be somewhere, is not in the animal, but in the Creator?

In treating of the parental affection in brutes, our business lies rather with the origin of the principle, than with the effects and expressions of it. Writers recount these with pleasure and admiration. The conduct of many kinds of animals towards their young, has escaped no observer, no historian of nature. "How will they caress them," says Derham, "with their affectionate notes; lull and quiet them with their tender parental voice; put f

into their mouths; cherish, and keep them warm; teach them to pick, and eat, and gather food for themselves; and, in a word, perform the part of so many nurses, deputed by the sovereign Lord and preserver of the world, to help such young and shiftless creatures?" Neither ought it, under this head, to be forgotten, how much the instinct *costs* the animal which feels it; how much a bird, for example, gives up, by sitting upon her nest; how repugnant it is to her organization, her habits, and her pleasures. An animal, formed for liberty, submits to confinement, in the very season when every thing invites her abroad: what is more; an animal delighting in motion, made for motion, all whose motions are so easy and so free, hardly a moment, at other times, at rest, is, for many hours of many days together, fixed to her nest, as close as if her limbs were tied down by pins and wires. For my part, I never see a bird in that situation, but I recognize an invisible hand, detaining the contented prisoner from her fields and groves, for a purpose, as the event proves, the most worthy of the sacrifice, the most important, the most beneficial.

But the loss of liberty is not the whole of what the procreant bird suffers. Harvey tells us, that he has often found the female wasted to skin and bone by sitting upon her eggs.

One observation more, and I will dismiss the subject. The *pairing* of birds, and the *non-pairing* of beasts, forms a distinction, between the two classes, which shows that the conjugal instinct is modified with a reference to utility founded in the condition of the offspring. In quadrupeds, the young animal draws its nutriment from the body of the dam. The male parent neither does, nor can, contribute any part to its sustentation. In the feathered race, the young bird is supplied by an importation of food, to

procure and bring home, which, in a sufficient quantity for the demand of a numerous brood, requires the industry of both parents. In this difference we see a reason, for the vagrant instinct of the quadruped, and for the faithful love of the feathered mate.

CHAPTER XIX.

OF INSECTS.

WE are not writing a system of natural history; therefore, we have not attended to the classes, into which the subjects of that science are distributed. What we had to observe concerning different species of animals, fell easily, for the most part, within the divisions, which the course of our argument led us to adopt. There remain, however, some remarks upon the *insect* tribe, which could not properly be introduced under any of these heads; and which, therefore, we have collected into a chapter by themselves.

The structure, and the use of the parts, of insects, are less understood than that of quadrupeds and birds, not only by reason of their minuteness, or the minuteness of their parts, (for that minuteness we can, in some measure, follow with glasses) but also, by reason of the remoteness of their manners and modes of life from those of larger animals. For instance; insects, under all their varieties of form, are endowed with *antennæ*, which is the name given to those long feelers that rise from each side of the head; but to what common use or want of the insect kind, a provision so universal is subservient, has not yet been ascertained; and it has not been ascertained, because it admits

not of a clear, or very probable comparison, with any organs which we possess ourselves, or with the organs of animals which resemble ourselves in their functions and faculties, or with which we are better acquainted than we are with insects. We want a ground of analogy. This difficulty stands in our way as to some particulars in the insect constitution which we might wish to be acquainted with. Nevertheless, there are many contrivances in the bodies of insects, neither dubious in their use, nor obscure in their structure, and most properly mechanical. These form parts of our argument.

I. The *elytra*, or scaly wings of the genus of scarabæus or beetle, furnish an instance of this kind. The true wing of the animal is a light transparent membrane, finer than the finest gauze, and not unlike it. It is also when expanded, in proportion to the size of the animal, very large. In order to protect this delicate structure, and, perhaps, also to preserve it in a due state of suppleness and humidity, a strong, hard, case is given to it, in the shape of the horny wing which we call the elytron. When the animal is at rest, the gauze wings lie folded up under this impenetrable shield. When the beetle prepares for flying, he raises the integument, and spreads out his thin membrane to the air. And it cannot be observed without admiration, what a tissue of cordage, i. e. of muscular tendons, must run, in various and complicated, but determinate directions, along this fine surface, in order to enable the animal, either to gather it up into a certain precise form, whenever it desires to place its wings under the shelter which nature hath given to them: or to expand again their folds, when wanted for action.

In some insects, the elytra cover the whole body; in others, half; in others, only a small part of it; but in all they completely hide and cover the true wings. Also,

Many or most of the beetle species lodge in holes in the earth, environed by hard, rough, substances, and have frequently to squeeze their way through narrow passages; in which situation, wings so tender, and so large, could scarcely have escaped injury, without both a firm covering to defend them, and the capacity of collecting themselves up under its protection.

II. Another contrivance, equally mechanical, and equally clear, is the *awl* or borer, fixed at the tails of various species of flies; and with which they pierce, in some cases, plants; in others, wood; in others, the skin and flesh of animals; in others, the coat of the chrysalis of insects of a different species from their own; and in others, even lime, mortar, and stone. I need not add, that having pierced the substance, they deposit their eggs in the hole. The descriptions, which naturalists give of this organ, are such as the following:—It is a sharp-pointed instrument, which, in its inactive state, lies concealed in the extremity of the abdomen, and which the animal draws out at pleasure, for the purpose of making a puncture in the leaves, stem, or bark of the particular plant, which is suited to the nourishment of its young. In a sheath, which divides and opens whenever the organ is used, there is inclosed, a compact, solid, dentated stem, along which runs a *gutter*, or *groove*, by which groove, after the penetration is effected, the egg, assisted, in some cases, by a peristaltic motion, passes to its destined lodgment. In the œstrum or gadfly, the wimble *draws out* like the pieces of a spy-glass; the last piece is armed with three hooks, and is able to bore through the hide of an ox. Can any thing more be necessary to display the mechanism, than to relate the fact?

III. The *stings* of insects, though for a different purpose, are, in their structure, not unlike the piercer. The

sharpness to which the point in all of them is wrought; the temper and firmness of the substance of which it is composed; the strength of the muscles by which it is darted out, compared with the smallness and weakness of the insect, and with the soft or friable texture of the rest of the body; are properties of the sting to be noticed, and not a little to be admired. The sting of a *bee* will pierce through a goatskin glove. It penetrates the human skin more readily than the finest point of a needle. The *action* of the sting affords an example of the union of chymistry and mechanism, such as, if it be not a proof of contrivance, nothing is. First, as to the chymistry; how highly concentrated must be the *venom*, which, in so small a quantity, can produce such powerful effects? And in the bee we may observe, that this venom is made from *honey*, the only food of the insect, but the last material from which I should have expected, that an exalted poison could, by any process of digestion whatsoever, have been prepared. In the next place, with respect to the mechanism, the sting is not a simple, but a compound instrument. The visible sting, though drawn to a point exquisitely sharp, is in strictness only a sheath; for, near to the extremity, may be perceived by the microscope two minute orifices, from which orifices, in the act of stinging, and, as it should seem, after the point of the main sting has buried itself in the flesh, are launched out two subtile rays, which may be called the true or proper stings, as being those, through which the poison is infused into the puncture already made by the exterior sting. I have said that chymistry and mechanism are here *united*: by which observation I meant, that all this machinery would have been useless, telum imbelle, if a supply of poison, intense in quality, in proportion to the smallness of the drop, had not been furnished to it by the chymical elaboration which was carried on

in the insect's body: and that, on the other hand, the poison, the result of this process, could not have attained its effect, or reached its enemy, if, when it was collected at the extremity of the abdomen, it had not found there a machinery, fitted to conduct it to the external situations in which it was to operate, viz. an awl to bore a hole, and a syringe to inject the fluid. Yet these attributes, though combined in their action, are independent in their origin. The venom does not breed the sting; nor does the sting concoct the venom.

IV. The *proboscis*, with which many insects are endowed, comes next in order to be considered. It is a tube attached to the head of an animal. In the bee, it is composed of two pieces, connected by a joint: for, if it were constantly extended, it would be too much exposed to accidental injuries: therefore, in its indolent state, it is doubled up by means of the joint, and in that position lies secure under a scaly pent-house. In many species of the butterfly, the proboscis, when not in use, is coiled up like a watch spring. In the same bee, the proboscis serves the office of the mouth, the insect having no other: and how much better adapted it is, than a mouth would be, for the collecting of the proper nourishment of the animal, is sufficiently evident. The food of the bee is the nectar of flowers; a drop of syrup, lodged deep in the bottom of the corollæ, in the recesses of the petals, or down the neck of a monopetalous glove. Into these cells the bee thrusts its long narrow pump, through the cavity of which it sucks up this precious fluid, inaccessible to every other approach. The ringlets of which the proboscis of the bee is composed, the muscles by which it is extended and contracted, form so many microscopical wonders. The agility also, with which it is moved, can hardly fail to excite

admiration. But it is enough for our purpose to observe in general, the suitableness of the structure to the use, of the means to the end, and especially the wisdom, by which nature has departed from its most general analogy (for animals being furnished with mouths is such) when the purpose could be better answered by the deviation.

In some insects, the proboscis, or tongue, or trunk, is shut up in a sharp-pointed sheath, which sheath, being of a much finer texture than the proboscis itself, as well as sharpened at the point, pierces the substance which contains the food, and then *opens within the wound*, to allow the inclosed tube, through which the juice is extracted, to perform its office. Can any mechanism be plainer than this is; or surpass this?

V. The *metamorphosis* of insects from grubs into moths and flies, is an astonishing process. A hairy caterpillar is transformed into a butterfly. Observe the change. We have four beautiful wings, where there were none before; a tubular proboscis, in the place of a mouth with jaws and teeth; six long legs, instead of fourteen feet. In another case, we see a white, smooth, soft worm, turned into a black, hard, crustaceous beetle, with gauze wings. These, as I said, are astonishing processes, and must require, as it should seem, a proportionably artificial apparatus. The hypothesis which appears to me most probable is, that, in the grub, there exist at the same time three animals, one within another, all nourished by the same digestion, and by a communicating circulation; but in different stages of maturity. The latest discoveries, made by naturalists, seem to favour this supposition. The insect already equipped with wings, is descried under the membranes, both of the worm and the nymph. In some species, the proboscis, the antennæ, the limbs and wings of the fly, have been observed to be folded up within the body of the

caterpillar; and with such nicety, as to occupy a small space only under the two first rings. This being so, the outermost animal, which, beside its own proper character, serves as an integument to the other two, being the furthest advanced, dies, as we suppose, and drops off first. The second, the pupa or chrysalis, then offers itself to observation. This also, in its turn, dies; its dead and brittle husk falls to pieces, and makes way for the appearance of the fly or moth. Now, if this be the case, or indeed whatever explication be adopted, we have a prospective contrivance of the most curious kind: we have organizations *three deep*, yet a vascular system, which supplies nutrition, growth, and life, to all of them together.

VI. Almost all insects are oviparous. Nature keeps her butterflies, moths and caterpillars, locked up during the winter in their egg state; and we have to admire the various devices, to which, if we may so speak, the same nature hath resorted, for the *security* of the egg. Many insects inclose their eggs in a silken web; others cover them with a coat of hair, torn from their own bodies; some glue them together; and others, like the moth of the silk-worm, glue them to the leaves upon which they are deposited, that they may not be shaken off by the wind, or washed away by rain: some again make incisions into leaves, and hide an egg in each incision; whilst some envelope their eggs with a soft substance, which forms the first aliment of the young animal; and some again make a hole in the earth, and, having stored it with a quantity of proper food, deposite their egg in it. In all which we are to observe, that the expedient depends, not so much upon the address of the animal, as upon the physical resources of his constitution.

The art also with which the young insect is *coiled up* in the egg, presents, where it can be examined, a subject of

great curiosity. The insect, furnished with all the members which it ought to have, is rolled up into a form which seems to contract it into the least possible space; by which contraction, notwithstanding the smallness of the egg, it has room enough in its apartment, and to spare. This folding of the limbs appears to me to indicate a special direction; for, if it were merely the effect of compression, the collocation of the parts would be more various than it is. In the same species, I believe, it is always the same.

These observations belong to the whole insect tribe, or to a great part of them. Other observations are limited to fewer species; but not, perhaps, less important or satisfactory.

I. The organization in the abdomen of the *silk-worm* or *spider*, whereby these insects form their *thread*, is as incontestably mechanical, as a wire-drawer's mill. In the body of the silk-worm are two bags, remarkable for their form, position, and use. They wind round the intestine; when drawn out they are ten inches in length, though the animal itself be only two. Within these bags is collected a glue; and communicating with the bags, are two paps or outlets, perforated, like a garter, by a number of small holes. The glue or gum, being passed through these minute apertures, forms hairs of almost imperceptible fineness; and these hairs, when joined, compose the silk which we wind off from the cone, in which the silk-worm has wrapped itself up: in the spider the web is formed of this thread. In both cases, the extremity of the thread, by means of its adhesive quality, is first attached by the animal to some external hold; and the end being now fastened to a point, the insect, by turning round its body, or by receding from that point, draws out the thread through the holes above described, by an operation, as hath been observed, exactly similar to the drawing of wire. The

thread, like the wire, is formed by the hole through which it passes. In one respect there is a difference. The wire is the metal unaltered, except in figure. In the animal process, the nature of the substance is somewhat changed, as well as the form: for, as it exists within the insect, it is a soft, clammy, gum or glue. The thread acquires, it is probable, its firmness and tenacity from the action of the air upon its surface, in the moment of exposure; and a thread so fine is almost all surface. This property, however, of the paste, is part of the contrivance.

The mechanism itself consists of the bags, or reservoirs, into which the glue is collected, and of the external holes communicating with these bags: and the action of the machine is seen, in the forming of a thread, as a wire is formed, by forcing the material already prepared, through holes of proper dimensions. The secretion is an act too subtile for our discernment, except as we perceive it by the produce. But one thing answers to another: the secretory glands to the quality and consistence required in the secreted substance; the bag to its reception. The outlets and orifices are constructed, not merely for relieving the reservoirs of their burthen, but for manufacturing the contents into a form and texture, of great external use, or rather indeed of future necessity, to the life and functions of the insect.

II. Bees, under one character or other, have furnished every naturalist with a set of observations. I shall, in this place, confine myself to one; and that is the *relation* which obtains between the wax and the honey. No person, who has inspected a bee-hive, can forbear remarking, how commodiously the honey is bestowed in the comb: and amongst other advantages, how effectually the fermentation of the honey is prevented by distributing it into small cells. The fact is, that when the honey is separated from

the comb, and put into jars, it runs into fermentation, with a much less degree of heat than what takes place in a hive. This may be reckoned a nicety: but independently of any nicety in the matter, I would ask, what could the bee do with the honey, if it had not the wax? how, at least, could it store it up for winter? The wax, therefore, answers a purpose with respect to the honey; and the honey constitutes that purpose with respect to the wax. This is the relation between them. But the two substances, though, together, of the greatest use, and, without each other, of little, come from a different origin. The bee finds the honey, but makes the wax. The honey is lodged in the nectaria of flowers, and probably undergoes little alteration; is merely collected; whereas the wax is a ductile tenacious paste, made out of a dry powder, not simply by kneading it with a liquid, but by a digestive process in the body of the bee. What account can be rendered of facts so circumstanced, but that the animal, being intended to feed upon honey, was, by a peculiar external configuration, enabled to procure it? that, moreover, wanting the honey when it could not be procured at all, it was further endued with the no less necessary faculty of constructing repositories for its preservation? which faculty, it is evident, must depend, primarily, upon the capacity of providing suitable materials. Two distinct functions go to make up the ability. First, the power in the bee, with respect to wax, of loading the farina of flowers upon its thighs: microscopic observers speak of the spoon-shaped appendages, with which the thighs of bees are beset for this very purpose: but inasmuch as the art and will of the bee may be supposed to be concerned in this operation, there is, secondly, that which doth not rest in art or will, a digestive faculty which converts the loose powder into a stiff substance. This is a just account of

the honey and the honey comb; and this account, through every part, carries a creative intelligence along with it.

The *sting* also of the bee has this relation to the honey, that it is necessary for the protection of a treasure which invites so many robbers.

III. Our business is with mechanism. In the *panorpa* tribe of insects, there is a forceps in the tail of the male insect, with which he catches and holds the female. Are a pair of pincers more mechanical, than this provision, in their structure? or is any structure more clear and certain in its design?

IV. St. Pierre tells us,* that in a fly with six feet, (I do not remember that he describes the species) the pair next the head, and the pair next the tail, have brushes at their extremities, with which the fly dresses, as there may be occasion, the anterior or the posterior part of its body; but that the middle pair have no such brushes, the situation of these legs not admitting of the brushes, if they were there, being converted to the same use. This is a very exact mechanical distinction.

V. If the reader, looking to our distributions of science; wish to contemplate the chymistry, as well as the mechanism of nature, the insect creation will afford him an example. I refer to the light in the tail of a *glow-worm*. Two points seem to be agreed upon by naturalists concerning it: first, that it is phosphoric; secondly, that its use is to attract the male insect. The only thing to be inquired after, is the singularity, if any such there be, in the natural history of this animal, which should render a provision of this kind more necessary for it, than for other insects. That singularity seems to be the difference, which subsists between the male and the female; which difference is greater than what we find in any other spe-

* Vol. i. p. 342.

cies of animal whatever. The glow-worm is a female *caterpillar;* the male of which is a *fly;* lively, comparatively small, dissimilar to the female in appearance, probably also as distinguished from her in habits, pursuits, and manners, as he is unlike in form and external constitution. Here then is the adversity of the case. The caterpillar cannot meet her companion in the air. The winged rover disdains the ground. They might never therefore be brought together, did not this radiant torch direct the volatile mate to his sedentary female.

In this example we also see the resources of art anticipated. One grand operation of chymistry is the making of phosphorus; and it was thought an ingenious device, to make phosphoric matches supply the place of lighted tapers. Now this very thing is done in the body of the glow-worm. The phosphorus is not only made, but kindled; and caused to emit a steady and genial beam, for the purpose which is here stated, and which I believe to be the true one.

VI. Nor is the last the only instance that entomology affords, in which our discoveries, or rather our projects, turn out to be imitations of nature. Some years ago, a plan was suggested, of producing propulsion by re-action in this way. By the force of a steam engine, a stream of water was to be shot out of the stern of a boat; the impulse of which stream upon the water in the river, was to push the boat itself forward: it is, in truth, the principle by which sky-rockets ascend in the air. Of the use or the practicability of the plan I am not speaking; nor is it my concern to praise its ingenuity; but it is certainly a contrivance. Now, if naturalists are to be believed, it is exactly the device, which nature has made use of, for the motion of some species of aquatic insects. The larva of the *dragon fly*, according to Adams, swims by ejecting

water from its tail; is driven forwards by the re-action of water in the pool upon the current issuing in a direction backward from its body.*

VII. Again; Europe has lately been surprised by the elevation of bodies in the air by means of a balloon. The discovery consisted in finding out a manageable substance, which was, bulk for bulk, lighter than air; and the application of the discovery was, to make a body composed of this substance, bear up, along with its own weight, some heavier body which was attached to it. This expedient, so new to us, proves to be no other than what the author of nature has employed in the *gossamir spider*. We frequently see this spider's thread floating in the air, and extended from hedge to hedge, across a road or brook of four or five yards width. The animal which forms the thread, has no wings wherewith to fly from one extremity to the other of this line; nor muscles to enable it to spring or dart to so great a distance. Yet its Creator hath laid for it a path in the atmosphere; and after this manner. Though the animal itself be heavier than the air, the thread which it spins from its bowels is specifically lighter. This is its *balloon*. The spider left to itself would drop to the ground; but, being tied to its thread, both are supported. We have here a very peculiar provision; and to a contemplative eye it is a gratifying spectacle, to see this insect wafted on her thread, sustained by a levity not her own, and traversing regions, which, if we examined only the body of the animal, might seem to have been forbidden to its nature.

* Our author has committed a slight mistake in philosophy by attributing that to re-action, which is nothing more than an effect of partial pressure in the fluid of the moving body.

I MUST now crave the reader's permission to introduce into this place, for want of a better, an observation or two upon the tribe of animals, whether belonging to land or water, which are covered by *shells*.

I. The *shells* of *snails* are a wonderful, a mechanical, and, if one might so speak concerning the works of nature, an original contrivance. Other animals have their proper retreats, their hybernacula also or winter quarters, but the snail carries these about with him. He travels with his tent; and this tent, though as was necessary, both light and thin, is completely impervious either to moisture or air. The young snail comes out of its egg with the shell upon its back; and the gradual enlargement which the shell receives, is derived from the slime excreted by the animal's skin. Now the aptness of this excretion to the purpose, its property of hardening into a shell, and the action, whatever it be, of the animal, whereby it avails itself of its gift, and of the constitution of its glands, (to say nothing of the work being commenced before the animal is born,) are things, which can, with no probability, be referred to any other cause than to express design; and that not on the part of the animal alone, in which design, though it might build the house, could not have supplied the material. The will of the animal could not determine the quality of the excretion. Add to which, that the shell of a snail, with its pillar and convolution, is a very artificial fabric; whilst a snail, as it should seem, is the most numb and unprovided of all artificers. In the midst of variety, there is likewise a regularity, which would hardly be expected. In the same species of snail the number of turns is, usually, if not always, the same. The sealing up of the mouth of the shell by the snail, is also well calculated for its warmth and security; but the cerate is not of the same substance with the shell.

II. Much of what has been observed of snails belongs to *shell-fish* and their *shells*, particularly to those of the univalve kind; with the addition of two remarks. One of which is upon the great strength and hardness of most of these shells. I do not know, whether, the weight being given, art can produce so strong a case as are some of these shells. Which defensive strength suits well with the life of an animal, that has often to sustain the dangers of a stormy element and a rocky bottom, as well as the attacks of voracious fish. The other remark is, upon the property in the animal excretion, not only of congealing, but of congealing or, as a builder would call it, setting in water, and into a cretaceous substance, firm and hard. This property is much more extraordinary, and, chymically speaking, more specific, than that of hardening in the air; which may be reckoned a kind of exsiccation, like the drying of clay into bricks.

III. In the *bivalve* order of shell-fish, cockles, muscles, oysters, &c. what contrivance can be so simple or so clear, as the insertion, at the back, of a tough, tendinous, substance, that becomes, at once, the ligament which binds the two shells together, and the *hinge* upon which they open and shut.

IV. The shell of a lobster's tail, in its articulations and overlappings, represents the jointed part of a coat of mail; or rather, which I believe to be the truth, a coat of mail is an imitation of a lobster's shell. The same end is to be answered by both: the same properties, therefore, are required in both, namely, hardness and flexibility, a covering which may guard the part without obstructing its motion. For this double purpose, the art of man, expressly exercised upon the subject, has not been able to devise any thing better than what nature presents to his observation. Is not this therefore mechanism, which the

mechanic, having a similar purpose in view, adopts? Is the structure of a coat of mail to be referred to art? Is the same structure of the lobster, conducing to the same use, to be referred to any thing less than art?

Some, who may acknowledge the imitation, and assent to the inference which we draw from it, in the instance before us, may be disposed, possibly, to ask, why such imitations are not more frequent than they are, if it be true, as we allege, that the same principle of intelligence, design, and mechanical contrivance, was exerted in the formation of natural bodies, as we employ in the making of the various instruments by which our purposes are served. The answers to this question are, first, that it seldom happens, that precisely the same purpose, and no other, is pursued in any work which we compare of nature and of art; secondly, that it still seldomer happens, that we *can* imitate nature, if we would. Our materials and our workmanship are equally deficient. Springs and wires, and cork and leather, produce a poor substitute for an arm or hand. In the example which we have selected, I mean of a lobster's shell compared with a coat of mail, these difficulties stand less in the way, than in almost any other that can be assigned; and the consequence is, as we have seen, that art gladly borrows from nature her contrivance, and imitates it closely.

But to return to insects. I think it is in this class of animals, above all others, especially when we take in the multitude of species which the microscope discovers, that we are struck with what Cicero has called "the *insatiable* variety of nature." There are said to be six thousand species of flies; seven hundred and sixty butterflies; each different from all the rest, (St. Pierre.) The same writer

tells us from his own observation, that thirty-seven species of winged insects, with distinctions well expressed, visited a single strawberry plant in the course of three weeks.* *Ray* observed, within the compass of a mile or two of his own house, two hundred kinds of butterflies, nocturnal, and diurnal. He likewise asserts, but, I think, without any grounds of exact computation, that the number of species of insects, reckoning all sorts of them, may not be short of ten thousand.† And in this vast variety of animal forms, (for the observation is not confined to insects, though more applicable perhaps to them than to any other class,) we are sometimes led to take notice of the different methods, or rather of the studiously diversified methods, by which one and the same purpose is attained. In the article of breathing, for example, which was to be provided for in some way or other, beside the ordinary varieties of lungs, gills, and breathing-holes, (for insects in general respire, not by the mouth, but through holes in the sides,) the nymphæ of gnats have an apparatus to raise their *backs* to the top of the water, and so take breath. The hydrocanthari do the like by thrusting their *tails* out of the water.‡ The maggot of the eruca labra has a long tail, one part sheathed within another, (but which it can draw out at pleasure,) with a starry tuft at the end, by which *tuft*, when expanded upon the surface, the insect both supports itself in the water, and draws in the air which is necessary. In the article of natural clothing, we have the skins of animals invested with scales, hair, feathers, mucus, froth; or itself turned into a shell or crust: in the no less necessary article of offence and defence, we have teeth, talons, beaks, horns, stings, prickles, with (the most singular expedient for the same pur-

* Vol. i. p. 3. † Wisd. of God, p. 23. ‡ Derham, p. 7.

pose) the power of giving the electric shock, and, as is credibly related of some animals, of driving away their pursuers by an intolerable fœtor, or of blackening the water through which they are pursued. The consideration of these appearances might induce us to believe, that *variety* itself, distinct from every other reason, was a motive in the mind of the Creator, or with the agents of his will.

To this great variety in organized life the Deity has given, or perhaps there arises out of it, a corresponding variety of animal *appetites*. For the final cause of this we have not far to seek. Did all animals covet the same element, retreat, or food, it is evident how much fewer could be supplied and accommodated, than what at present live conveniently together, and find a plentiful subsistence. What one nature rejects, another delights in. Food, which is nauseous to one tribe of animals, becomes by that very property which makes it nauseous, an alluring dainty to another tribe. Carrion is a treat to dogs, ravens, vultures, fish. The exhalations of corrupted substances attract flies by crowds. Maggots revel in putrefaction.

CHAPTER XX.

OF PLANTS.

I THINK a designed and studied mechanism to be in general, more evident in animals, than in *plants:* and it is unnecessary to dwell upon a weaker argument, where a stronger is at hand. There are, however, a few observations upon the vegetable kingdom, which lie so directly in our way, that it would be improper to pass them by without notice.

The one great intention of nature in the structure of plants, seems to be the perfecting of the *seed;* and, what is part of the same intention, the preserving of it until it be *perfected.* This intention shows itself, in the first place, by the care which appears to be taken to protect and ripen, by every advantage which can be given to them of situation in the plant, those parts which most immediately contribute, to fructification, viz. the antheræ, the stamina, and the stigmata. These parts are usually lodged in the centre, the recesses, or the labyrinths of the flower; during their tender and immature state, are shut up in the stalk, or sheltered in the bud; as soon as they have acquired firmness of texture sufficient to bear exposure, and are ready to perform the important office which is assigned to them, they are disclosed to the light and air, by the bursting of the stem or the expansion of the petals: after which they have, in many cases, by the very form of the flower during its blow, the light and warmth reflected upon them from the concave side of the cup. What is called also the *sleep* of plants, is the leaves of petals disposing themselves in such a manner as to shelter the young stem, buds, or fruit. They turn up, or they fall down, according as this purpose renders either change or position requisite. In the growth of corn, whenever the plant begins to shoot, the two upper leaves of the stalk join together; embrace the ear; and protect it till the pulp has acquired a certain degree of consistency. In some water plants, the flowering and fecundation are carried on *within* the stem, which afterwards opens to let loose the impregnated seed.* The *pea* or papilionaceous tribe inclose the parts of fructification within a beautiful folding of the internal blossom, sometimes called from its shape, the boat or keel; itself also protected under a penthouse

* Phil. Trans. part, ii. 1796, p. 502.

formed by the external petals. This structure is very artificial; and, what adds to the value of it though it may diminish the curiosity, very general. It has also this further advantage (and it is an advantage strictly mechanical) that all the blossoms turn their *backs* to the wind, whenever the gale blows strong enough to endanger the delicate parts upon which the seed depends. I have observed this a hundred times in a field of peas in blossom. It is an aptitude which results from the figure of the flower, and, as we have said, is strictly mechanical; as much so, as the turning of a weather-board or tin cap upon the top of a chimney. Of the *poppy*, and of many similar species of flowers, the head, while it is growing, hangs down, a rigid curvature in the upper part of the stem giving to it that position; and in that position it is impenetrable by rain or moisture. When the head has acquired its size, and is ready to open, the stalk *erects* itself, for the purpose, as it should seem, of presenting the flower, and, with the flower, the instruments of fructification, to the genial influence of the sun's rays. This always struck me as a curious property; and specifically, as well as originally, provided for in the constitution of the plant: for, if the stem be only bent by the weight of the head, how comes it to straighten itself when the head is the heaviest? These instances show the attention of nature to this principal object, the safety and maturation of the parts upon which the seed depends.

In *trees*, especially in those which are natives of colder climates, this point is taken up earlier. Many of these trees (observe in particular the *ash* and the *horse-chesnut*) produce the embryos of the leaves and flowers in one year, and bring them to perfection the following. There is a winter therefore to be got over. Now what we are to remark is, how nature has prepared for the trials and sever-

ities of that season. These tender embryos, are, in the first place, wrapped up with a compactness, which no art can imitate: in which state, they compose what we call the bud. This is not all. The bud itself is inclosed in scales; which scales are formed from the remains of past leaves, and the rudiments of future ones. Neither is this the whole. In the coldest climates a third preservative is added, by the bud having a *coat* of gum or resin, which being congealed resists the strongest frosts. On the approach of warm weather this gum is softened, and ceases to be a hindrance to the expansion of the leaves and flowers. All this care is part of that system of provisions which has for its object and consummation, the production and perfecting of the seeds.

The SEEDS themselves are packed up in a *capsule*, a vessel composed of coats, which compared with the rest of the flower, are strong and tough. From this vessel projects a tube, through which tube the ferina, or some subtile fecundating effluvium that issues from it, is admitted to the seed. And here also occurs a mechanical variety, accommodated to the different circumstances under which the same purpose is to be accomplished. In flowers which are erect, the pistil is shorter than the stamina; and the pollen, shed from the antheræ into the cup of the flower, is catched in its descent by the head of the pistil, called the stigma. But how is this managed when the flowers hang down, (as does the crown imperial, for instance) and in which position, the farina, in its fall, would be carried from the stigma, and not towards it? The relative length of the parts is now inverted. The pistil in these flowers is usually longer, instead of shorter, than the stamina, that its protruding summit may receive the pollen as it drops to the ground. In some cases, (as in the *nigella*,) where the shafts of the pistils, or styles are disproportion-

ably long, they bend down their extremities upon the antheræ, that the necessary approximation may be effected.

But (to pursue this great work in its progress,) the impregnation, to which all this machinery relates, being completed, the other parts of the flower fade and drop off, whilst the *graved seed-vessel*, on the contrary, proceeds to increase its bulk, always to a great, and in some species, (in the gourd, for example, and melon,) to a surprising comparative size; assuming in different plants an incalculable variety of forms, but all evidently conducing to the security of the seed. By virtue of this process so necessary, but so diversified, we have the seed, at length, in stone fruits and nuts, incased in a strong shell, the shell itself inclosed in a pulp or husk, by which the seed within is, or hath been, fed; or, more generally (as in grapes, oranges, and the numerous kinds of berries) plunged over head in a glutinous syrup, contained within a skin or bladder: at other times (as in apples and pears) embedded in the heart of a firm, fleshy substance; or, (as in strawberries) pricked into the surface of a soft pulp.

These and many other varieties exist in what we call *fruits*.* In pulse, and grain, and grasses; in trees, and

* From the conformation of fruits alone, one might be led, even without experience, to suppose, that part of this provision was destined for the utilities of animals. As limited to the plant, the provision itself seems to go beyond its object. The flesh of an apple, the pulp of an orange, the meat of a plumb, "the fatness of the olive," appear to be more than sufficient for the nourishing of the seed or kernel. The event shows that this redundancy, if it be one, ministers to the support and gratification of animal natures: and when we observe a provision to be more than sufficient for one purpose, yet wanted for another purpose, it is not unfair to conclude that both purposes were contemplated together. It favours this view of the subject to remark, that fruits are not (which they might have been) ready altogether, but that they ripen in succession throughout a great part of the year; some in summer; some in autumn; that some require the slow maturation of the winter, and

shrubs, and flowers; the variety of the seed-vessels is incomputable. We have the seed (as in the pea tribe) regularly disposed in parchment pods, which, though soft, and membranous, completely exclude the wet even in the heaviest rains; the pod also, not seldom (as in the bean) lined with a fine down; at other times (as in the senna) distended like a blown bladder: or we have the seed involved in wool (as in the cotton plant,) lodged (as in pines) between the hard and compact scales of a cone; or barricadoed (as in the artichoke and thistle) with spikes and prickles; in mushrooms, placed under a penthouse; in ferns, within slits in the back part of the leaf; or (which is the most general organization of all) we find them covered by strong, close, tunicles, and attached to the stem according to an order appropriated to each plant, as is seen in the several kinds of grain, and of grasses.

In which enumeration what we have first to notice is, unity of purpose under variety of expedients. Nothing can be more *single* than the design; more *diversified* than the means. Pellicles, shells, pulps, pods, husks, skins, scales armed with thorns, are all employed in prosecuting the same intention. Secondly; we may observe, that, in all these cases, the purpose is fulfilled within a just and *limited* degree. We can perceive, that, if the seeds of plants were more strongly guarded than they are, their greater security would interfere with other uses. Many species of animals would suffer, and many perish, if they could not obtain access to them. The plant would overrun the soil; or the seed be wasted for the want of room to sow itself. It is, sometimes, as necessary to destroy particu-

supply the spring: also, that the coldest fruits grow in the hottest places. Cucumbers, pine-apples, melons, are the natural produce of warm climates, and contribute greatly, by their coolness, to the refreshment of the inhabitants of those countries.

lar species of plants, as it is, at other times, to encourage their growth. Here, as in many cases, a balance is to be maintained between opposite uses. The provisions for the preservation of seeds appear to be directed, chiefly against the inconstancy of the elements, or the sweeping destruction of inclement seasons. The depredations of animals, and the injuries of accidental violence, are allowed for in the abundance of the increase. The result is, that, out of the many thousand different plants which cover the earth, not a single species, perhaps, has been lost since the creation.

When nature has perfected her seeds, her next care is to disperse them. The seed cannot answer its purpose, while it remains confined in the capsule. After the seeds therefore are ripened, the pericarpium opens to let them out; and the opening is not like an accidental bursting, but, for the most part, is according to a certain rule in each plant. What I have always thought very extraordinary, nuts and shells, which we can hardly crack with our teeth, divide and make way for the little tender sprout which proceeds from the kernel. Handling the nut, I could hardly conceive how the plantule was ever to get out of it. There are cases, it is said, in which the seed-vessel by an elastic jerk, at the moment of its explosion, casts the seed to a distance. We all however know, that many seeds (those of the most composite flowers, as of the thistle, dandelion, &c.) are endowed with what are not improperly called *wings;* that is, downy appendages, by which they are enabled to float in the air, and are carried oftentimes by the wind to great distances from the plant which produces them. It is the swelling also of this downy tuft within the seed-vessel, that seems to overcome the resistance of its coats, and to open a passage for the seed to escape.

But the *constitution* of seeds is still more admirable than either their preservation or their dispersion. In the body of the seed of every species of plant, or nearly of every one, provision is made for two grand purposes: first, for the safety of the *germ;* secondly, for the temporary support of the future plant. The sprout, as folded up in the seed, is delicate and brittle, beyond any other substance. It cannot be touched without being broken. Yet, in beans, peas, grass-seeds, grain, fruits, it is so fenced on all sides, so shut up and protected, that, whilst the seed itself is rudely handled, tossed into sacks, shovelled into heaps, the miniature plant, the sacred particle, remains unhurt. It is wonderful also, how long many kinds of seed, by the help of their integuments, and perhaps of their oils, stand out against decay. A grain of mustard seed has been known to lie in the earth for a hundred years; and, as soon as it had acquired a favourable situation, to shoot as vigorously as if just gathered from the plant. Then, as to the second point, the temporary support of the future plant, the matter stands thus. In grain, and pulse, and kernels, and pippins, the germ composes a very small part of the seed. The rest consists of a nutritious substance, from which the sprout draws its aliment for some considerable time after it is put forth; viz. until the fibres, shot out from the other end of the seed, are able to imbibe juices from the earth, in a sufficient quantity for its demand. It is owing to this constitution, that we see seeds sprout, and the sprouts make a considerble progress without any earth at all. It is an economy also, in which we remark a close analogy between the seeds of plants, and the eggs of animals. The same point is provided for, in the same manner, in both. In the egg, the residence of the living principle, the cica-

trix, forms a very minute part of the contents. The white, and the white only, is expended in the formation of the chicken. The yolk, very little altered or diminished, is wrapped up in the abdomen of the young bird, when it quits the shell; and serves for its nourishment, till it has learnt to pick its own food. This perfectly resembles the first nutrition of a plant. In the plant, as well as in the animal, the structure has every character of contrivance belonging to it: in both it breaks the transition from prepared to unprepared aliment: in both it is prospective and compensatory. In animals which suck, this intermediate nourishment is supplied by a different source.

In all subjects the most common observations are the best, when it is their truth and strength which have made them common. There are, of this sort, *two* concerning plants, which it falls within our plan to notice. The *first* relates to, what has already been touched upon, their germination. When a grain of corn is cast into the ground, this is the change which takes place. From one end of the grain issues a green sprout: from the other a number of white fibrous threads. How can this be explained? Why not sprouts from both ends? Why not fibrous threads from both ends? To what is the difference to be referred, but to design; to the different uses which the parts are thereafter to serve; uses which discover themselves in the sequel of the process? The sprout, or plumule, struggles into the air; and becomes the plant, of which, from the first, it contained the rudiments: the fibres shoot into the earth; and, thereby, both fix the plant to the ground, and collect nourishment from the soil for its support. Now, what is not a little remarkable, the parts issuing from the seed take their respective directions, into whatever position the seed itself happens to be cast. If the seed be thrown into the wrongest pos-

sible position, that is, if the ends point in the ground, the reverse of what they ought to do, every thing, nevertheless, goes on right. The sprout, after being pushed down a little way, makes a bend and turns upwards; the fibres, on the contrary, after shooting at first upwards, turn down. Of this extraordinary vegetable fact an account has lately been attempted to be given. "The plumule, it is said, is stimulated by the *air* into action, and elongates itself when it is thus most excited: the radicle is stimulated by *moisture*, and elongates itself when *it* is thus most excited. Whence one of these grows upwards in quest of its adapted object, and the other downward."* Were this account better verified by experiment than it is, it only shifts the contrivance. It does not disprove the contrivance; it only removes it a little further back. Who, to use our author's own language, "adapted the objects?" Who gave such a quality to these connate parts, as to be susceptible of different "stimulation:" as to be "excited," each only by its own element, and precisely by that, which the success of the vegetation requires? I say, "which the success of the vegetation requires," for the toil of the husbandman would have been in vain; his laborious and expensive preparation of the ground in vain; if the event must, after all, depend upon the position in which the scattered seed was sown. Not one seed out of a hundred would fall in a right direction.

Our *second* observation is upon a general property of climbing plants, which is strictly mechanical. In these plants, from each knot or joint, or as botanists call it, axilla of the plant, issue, close to each other, two shoots; one, bearing the flower and fruit, the other, drawn out into a wire, a long, tapering, spiral tendril, that twists itself round any thing that lies within its reach. Consider-

* Darwin's Phytologia. p. 144.

ing, that, in this class, two purposes are to be provided for (and together,) fructification and support, the fruitage of the plant, and the sustentation of its stalk, what means could be used more effectual, or, as I have said, more mechanical, than what this structure presents to our eyes? Why or how, without a view to this double purpose, do two shoots, of such different and appropriate forms, spring from the same joint, from contiguous points of the same stalk? It never happens thus in robust plants, or in trees. "We see not," says Ray, so much as one tree, or shrub, or herb, that hath a firm and strong stem, and that is able to mount up and stand alone without assistance, *furnished with these tendrils.*" Make only so simple a comparison as that between a pea and a bean. Why does the pea put forth tendrils, the bean not; but because the stalk of the pea cannot support itself, the stalk of the bean can: we may add also, as a circumstance not to be overlooked, that, in the pea tribe, these clasps do not make their appearance, till they are wanted; till the plant has grown to a height to stand in need of support.

☞ This word "support," suggests to us a reflection upon the property of grasses, of corn, and canes. The hollow stems of these classes of plants, are set, at certain intervals, with joints. These joints are not found in the trunks of trees, or in the solid stalks of plants. There may be other uses of these joints; but the fact is, and it appears to be, at least, one purpose designed by them, that they *corroborate* the stem; which, by its length and hollowness, would, otherwise, be too liable to break or bend.

Grasses are nature's care. With these she clothes the earth: with these she sustains its inhabitants. Cattle feed upon their leaves; birds upon their smaller seeds; men upon the larger; for few readers need be told that the plants, which produce our bread corn, belong to this

class. In those tribes, which are more generally considered as grasses, their extraordinary means and powers of preservation and increase, their hardiness, their almost unconquerable disposition to spread, their faculties of reviviscence, coincide with the intention of nature concerning them. They thrive under a treatment by which other plants are destroyed. The more their leaves are consumed, the more their roots increase. The more they are trampled upon, the thicker they grow. Many of the seemingly dry and dead leaves of grasses revive, and renew their verdure, in the spring. In lofty mountains, where the summer heats are not sufficient to ripen the seeds, grasses abound, which are viviparous, and consequently able to propagate themselves without seed. It is an observation, likewise, which has often been made, that herbivorous animals attach themselves to the leaves of grasses; and, if at liberty in their pastures to range and choose, leave untouched the straws which support the flowers.*

The general properties of vegetable nature, or properties common to large portions of that kingdom, are almost all which the compass of our argument allows to bring forward. It is impossible to follow plants into their several species. We may be allowed, however, to single out three or four of these species as worthy of a particular notice, either by some singular mechanism, or by some peculiar provision, or by both.

In Dr. Darwin's Botanic Garden, line 395, note, is the following account of the *vallisneria*, as it has been observed in the river Rhone. "They have roots at the bottom of the Rhone. The flowers of the *female plant* float on the surface of the water, and are furnished with an

* With. Bot. Arr. vol. i. p. 28. ed. 2d.

elastic, spiral, stalk, which extends or contracts as the water rises or falls; this rise or fall, from the torrents which flow into the river, often amounting to many feet in a few hours. The flowers of the *male plant* are produced under water; and, as soon as the fecundating farina is mature, they separate themselves from the plant; rise to the surface; and are wafted by the air, or borne by the currents, to the female flowers." Our attention in this narrative will be directed to two particulars; first, to the mechanism, the "elastic, spiral, stalk" which lengthens or contracts itself according as the water rises or falls; secondly, to the provision which is made for bringing the male flower, which is produced *under* water, to the female flower which floats upon the surface.

II. My second example I take from Withering. (Arrang. vol. ii. p. 209. ed. 3.) "The *cuscuta europæ* is a parasitical plant. The seed opens, and puts forth a *little spiral body* which does NOT seek the earth to take root; but *climbs* in a spiral direction, from right to left, up other plants, from which, by means of vessels, it draws its nourishment." The "little spiral body" proceeding from the seed is to be compared with the fibres which seeds send out in ordinary cases; and the comparison ought to regard both the form of the threads and the direction. They are straight; this is spiral. They shoot downwards; this points upwards. In the rule, and in the exception, we equally perceive design.

III. A better known parasitical plant is the evergreen shrub, called the *misseltoe*. What we have to remark in it, is a singular instance of *compensation*. No art has yet made these plants take root in the earth. Here therefore might seem to be a mortal defect in their constitution. Let us examine how this defect is made up to them. The seeds are endued with an adhesive quality so tenacious, that, if

they be rubbed upon the smooth bark of almost any tree, they will stick to it. And then what follows? Roots springing from their seeds, insinuate their fibres into the woody substance of the tree; and the event is, that a misseltoe plant is produced the next winter.* Of no other plant do the roots refuse to shoot in the ground; of no other plant do the seeds possess this adhesive, generative, quality, when applied to the bark of trees.

IV. Another instance of the *compensatory* system in in the autumnal crocus or meadow saffron, *(cholcicum autumnale.)* I have pitied this poor plant a thousand times. Its blossom rises out of the ground in the most forlorn condition possible; without a sheath, a fence, a calyx, or even a leaf to protect it; and that, not in the spring, not to be visited by summer suns, but under all the disadvantages of the declining year. When we come however to look more closely into the structure of this plant, we find that, instead of its being neglected, nature has gone out of her course to provide for its security, and to make up to it for its defects. The seed-vessel, which in other plants is situated within the cup of the flower, or just beneath it, in this plant lies buried ten or twelve inches under ground within the bulbous root. The tube of the flower, which is seldom more than a few tenths of an inch long, in this plant extends down to the root. The styles always reach the seed-vessel; but it is in this, by an elongation unknown to any other plant. All these singularities contribute to one end. "As this plant blossoms late in the year, and, probably, would not have time to ripen its seeds before the access of winter which would destroy them, Providence has contrived its structure such, that this important office may be performed at a depth in the

* Ib. p. 203.

earth out of the reach of the usual effects of frost."* That is to say, in the autumn nothing is done above ground but the business of impregnation; which is an affair between the antheræ and the stigmata. The maturation of the impregnated seed, which in other plants proceeds within a capsule, exposed together with the rest of the flower to the open air, is here carried on, and during the whole winter, within the heart, as we may say, of the earth, that is, "out of the reach of the usual effects of frost." But then a new difficulty presents itself. Seeds, though perfected, are known not to vegetate at this depth in the earth. Our seeds therefore, though so safely lodged, would, after all, be lost to the purpose for which all seeds are intended. Lest this should be the case, "a second admirable provision is made to raise them above the surface when they are perfected, and to sow them at a proper distance:" viz. the germ grows up *in the spring*, upon a fruit stalk, accompanied with leaves. The seeds now, in common with those plants, have the benefit of the summer, and are sown upon the surface. The order of vegetation externally is this. The plant produces its flowers in September; its leaves and fruits in the spring following.

V. I give the account of the dionæa muscipula, an extraordinary American plant, as some late authors have related it; but, whether we be yet enough acquainted with the plant to bring every part of this acccount to the test of repeated and familiar observation, I am unable to say. Its leaves are jointed, and furnished with two rows of strong prickles; their surfaces covered with a number of minute glands, which secrete a sweet liquor, that allures the approach of flies. When these parts are touched by

* Ib. p. 360.

the legs of flies, the two lobes of the leaf instantly spring up, the rows of prickles lock themselves fast together, and squeeze the unwary animal to death."* Here, under a new model, we recognise the ancient plan of nature; viz. the relation of parts and provisions to one another, to a common office, and to the utility of the organized body to which they belong. The attracting syrup, the rows of strong prickles, their position so as to interlock, the joints of the leaves; and, what is more than the rest, that singular irritability of their surfaces, by which they close at a touch; all bear a contributory part in producing an effect, connected either with the defence, or with the nutrition, of the plant.

* Smellie's Phil. of Nat. Hist. vol. i. p. 5.

CHAPTER XXI.

THE ELEMENTS.

WHEN we come to the elements, we take leave of our mechanics; because we come to those things, of the organization of which, if they be organized, we are confessedly ignorant. This ignorance is implied by their name. To say the truth, our investigations are stopped long before we arrive at this point. But then it is for our comfort to find, that a knowledge of the constitution of the elements is not necessary for us. For instance, as Addison has well observed, "we know *water* sufficiently when we know how to boil, how to freeze, how to evaporate, how to make it fresh, how to make it run or spout out, in what quantity and direction we please, without knowing what water is." The observation of this excellent writer has more propriety in it now, than it had at

the time it was made: for the constitution, and the constituent parts of water, appear in some measure to have been lately discovered; yet it does not, I think, appear, that we can make any better or greater use of water since the discovery, than we did before it.

We can never think of the elements without reflecting upon the number of distinct uses which are *consolidated* in the same substance. The *air* supplies the lungs, supports fire, conveys sound, reflects light, diffuses smells, gives rain, wafts ships, bears up birds. Ex UDATOS TA PANTA; *water*, beside maintaining its own inhabitants, is the universal nourisher of plants, and through them of terrestrial animals; is the basis of their juices and fluids: dilutes their food, quenches their thirst, floats their burdens. *Fire* warms, dissolves, enlightens; is the great promoter of vegetation and life, if not necessary to the support of both.

We might enlarge, to almost any length we pleased, upon each of these uses; but it appears to me almost sufficient to state them. The few remarks which I judge it necessary to add, are as follow.

I. Air is essentially different from earth. There appears to be no necessity for an atmosphere's investing our globe: (the moon has none:) yet it does invest it; and we see how many, how various, and how important are the purposes which it answers to every order of animated, not to say of organized, beings, which are placed upon the terrestrial surface. I think that every one of these uses will be understood upon the first mention of them, except it be that of *reflecting* light, which may be explained thus. If I had the power of seeing only by means of rays coming directly from the sun; whenever I turned my back upon the luminary, I should find myself in darkness. If I had the power of seeing by reflected light, yet by means

only of light reflected from solid masses, these masses would shine, indeed, and glisten, but it would be in the dark. The hemisphere, the sky, the world, could only be *illuminated*, as it is illuminated, by the light of the sun being from all sides, and in every direction, reflected to the eye, by particles, as numerous, as thickly scattered, and as widely diffused, as are those of the air.

Another general quality of the atmosphere is, the power of evaporating fluids. The adjustment of this quality to our use is seen in its action upon the sea. In the sea, water and salt are mixed together most intimately; yet the atmosphere raises the water, and leaves the salt. Pure and fresh as drops of rain descend, they are collected from brine. If evaporation be solution, (which seems to be probable,) then the air dissolves the water and not the salt. Upon whatever it be founded, the distinction is critical; so much so, that, when we attempt to imitate the process by art, we must regulate our distillation with great care and nicety, or, together with the water, we get the bitterness, or, at least, the distatefulness of the marine substance: and, after all, it is owing to this original elective power in the air, that we can effect the separation which we wish, by any art or means whatever.

By evaporation water is carried up into the air; by the converse of evaporation it falls down upon the earth. And how does it fall? Not by the clouds being all at once converted into water, and descending, like a sheet; not in rushing down in columns from a spout; but in moderate drops, as from a cullender. Our watering-pots are made to imitate showers of rain. Yet, a priori, I should have thought either of the two former methods more likely to have taken place than the last.

By respiration, flame, putrefaction, air is rendered unfit for the support of animal life. By the constant ope-

ration of these corrupting principles, the whole atmosphere, if there were no restoring causes, would come at length to be deprived of its necessary degree of purity. Some of these causes seem to have been discovered, and their efficacy ascertained by experiment. And so far as the discovery has proceeded, it opens to us a beautiful and a wonderful economy. *Vegetation* proves to be one of them. A sprig of mint, corked up with a small portion of foul air placed in the light, renders it again capable of supporting life or flame. Here, therefore, is a constant circulation of benefits maintained between the two great provinces of organized nature. The plant purifies, what the animal had poisened: in return, the contaminated air is more than ordinarily nutritious to the plant. *Agitation with water* turns out to be another of these restoratives. The foulest air, shaken in a bottle with water for a sufficient length of time, recovers a great degree of its purity. Here then again, allowing for the scale upon which nature works, we see the salutary effects of *storms* and *tempests*. The yesty waves, which confound the heaven and the sea, are doing the very thing which is done in the bottle. Nothing can be of greater importance to the living creation, than the salubrity of their atmosphere. It ought to reconcile us therefore to these agitations of the elements, of which we sometimes deplore the consequences, to know, that they tend powerfully to restore to the air that purity, which so many causes are constantly impairing.

II. In WATER, what ought not a little to be admired, are those negative qualities which constitute its *purity*. Had it been vinous, or oleaginous, or acid; had the sea been filled, or the rivers flowed, with wine or milk; fish, constituted as they are, must have died; plants, constituted as they are, would have withered; the lives of animals, which feed upon plants, must have perished. Its very *in-*

vapidity, which is one of those negative qualities, renders it the best of all menstrua. Having no taste of its own, it becomes the sincere vehicle of every other. Had there been a taste in water, be it what it might, it would have infected every thing we ate or drank, with an importunate repetition of the same flavour.

Another thing in this element, not less to be admired, is the constant *round* which it travels; and by which, without suffering either adulteration or waste, it is continually offering itself to the wants of the habitable globe. From the sea are exhaled those vapours which form the clouds. These clouds descend in showers, which, penetrating into the crevices of the hills, supply springs. Which springs flow in little streams into the vallies; and, there uniting, become rivers. Which rivers, in return, feed the ocean. So there is an incessant circulation of the same fluid; and not one drop probably more or less now, than there was at the creation. A particle of water takes its departure from the surface of the sea, in order to fulfil certain important offices to the earth; and having executed the service which was assigned to it, returns to the bosom which it left.

Some have thought that we have too much water upon the globe; the sea occupying above three quarters of its whole surface. But the expanse of ocean, immense as it is, may be no more than sufficient to fertilize the earth. Or, independently of this reason, I know not why the sea may not have as good a right to its place as the land. It may proportionably support as many inhabitants; minister to as large an aggregate of enjoyment. The land only affords a habitable surface; the sea is habitable to a great depth.

III. Of FIRE, we have said that it *dissolves*. The only

idea probably which this term raised in the reader's mind was, that of fire melting metals, resins, and some other substances, fluxing ores, running glass, and assisting us in many of our operations, chymical or culinary. Now these are only uses of an occasional kind, and gives us a very imperfect notion o what fire does for us. The grand importance of this dissolving power, the great office indeed of fire in the economy of nature, is keeping things in a state of solution, that is to say, in a state of fluidity. Were it not for the presence of heat, or of a certain degree of it all fluids would be frozen. The ocean itself would be a quarry of ice; universal nature stiff and dead.

We see, therefore, that the elements bear, not only a strict relation to the constitution of organized bodies, but a relation to each other. Water could not perform its office to the earth without air; nor exist as water, without fire.

IV. Of LIGHT, (whether we regard it as of the same substance with fire, or as a different substance,) it is altogether superfluous to expatiate upon the use. No man disputes it. The observations, therefore, which I shall offer, respect that little which we seem to know of its constitution.

Light passes from the sun to the earth in eleven minutes; a distance, which it would take a cannon ball twenty-five years in going over! Nothing more need be said to show the velocity of light. Urged by such a velocity, with what *force* must its particles drive against, I will not say the eye, the tenderest of animal substances, but every substance, animate or inanimate, which stands in its way? It might seem to be a force sufficient to shatter to atoms the hardest bodies.

How then is this effect, the consequence of such prodigious velocity, guarded against? By a proportionable

minuteness of the particles of which light is composed. It is impossible for the human mind to imagine to itself any thing so small as a particle of light. But this extreme exility, though difficult to conceive is easy to prove. A drop of tallow, expended in the wick of a farthing candle, shall shed forth rays sufficient to fill a hemisphere of a mile diameter; and to fill it so full of these rays, that an aperture not larger than the pupil of an eye, wherever it be placed within the hemisphere, shall be sure to receive some of them. What floods of light are continually poured from the sun we cannot estimate; but the immensity of the sphere which is filled with its particles, even if it reached no further than the orbit of the earth, we can in some sort compute: and we have reason to believe, that, throughout this whole region, the particles of light lie, in latitude at least, near to one another. The spissitude of the sun's rays at the earth is such, that the number which falls upon a burning glass of an inch diameter, is sufficient, when concentrated, to set wood on fire.

The tenuity and the velocity of particles of light, as ascertained by separate observations, may be said to be proportioned to each other: both surpassing our utmost stretch of comprehension: but proportioned. And it is this proportion alone, which converts a tremendous element into a welcome visitor.

It has been observed to me by a learned friend, as having often struck his mind, that, if light had been made by a common artist, it would have been of one uniform *colour:* whereas, by its present composition, we have that variety of colours, which is of such infinite use to us for the distinguishing of objects; which adds so much to the beauty of the earth, and augments the stock of our innocent pleasures.

With which may be joined another reflection, viz. that,

considering light as compounded of rays of seven different colours, (of which there can be no doubt, because it can be resolved into these rays by simply passing it through a prism) the constituent parts must be well mixed and blended together, to produce a fluid, so clear and colourless, as a beam of light is, when received from the sun.

CHAPTER XXII.

ASTRONOMY.*

MY opinion of Astronomy has always been, that it is *not* the best medium through which to prove the agency of an intelligent Creator; but that, this being proved, it shows beyond all other sciences, the magnificence of his operations. The mind, which is once convinced, it raises to sublimer views of the Deity, than any other subject affords; but is not so well adapted, as some other subjects are, to the purpose of argument. We are destitute of the means of examining the constitution of the heavenly bodies. The very simplicity of their appearance is against them. We see nothing, but bright points, luminous circles, or the phases of spheres reflecting the light which falls upon them. Now we deduce design from relation, aptitude, and correspondence of *parts*. Some degree therefore of *complexity* is necessary to render a subject fit for this species of argument. But the heavenly bodies do not except perhaps in the instance of Saturn's ring, present themselves to our observation as compounded of parts at

* For the articles in this chapter marked with an asterisk, I am indebted to some obliging communications, received (through the hands of the Lord Bishop of Elphin) from the Rev. J. Brinkley, M. A. Andrew's Professor of Astronomy in the University of Dublin.

all. This, which may be a perfection in them, is a disadvantage to us, as inquirers after their nature. They do not come within our mechanics.

And what we say of their forms is true of their *motions*. Their motions are carried on without any sensible intermediate apparatus: whereby we are cut off from one principal ground of argumentation and analogy. We have nothing wherewith to compare them; no invention, no discovery, no operation or resource of art, which, in this respect, resembles them. Even those things which are made to imitate and represent them, such as orreries, planetaria, celestial globes, &c., bear no affinity to them, in the cause and principle by which their motions are actuated. I can assign for this difference a reason of utility, viz. a reason why, though the action of *terrestrial* bodies upon each other be, in almost all cases, through the intervention of solid or fluid substances, yet central attraction does not operate in this manner. It was necessary that the intervals between the planetary orbs should be devoid of any *inert* matter, either fluid or solid, because such an intervening substance would, by its resistance, destroy those very motions, which attraction is employed to preserve. This may be a final cause of the difference; but still the difference destroys the analogy.

Our ignorance, moreover, of the *sensitive* natures, by which other planets are inhabited, necessarily keeps from us the knowledge of numberless utilities, relations, and subserviencies, which we perceive upon our own globe.

After all; the real subject of admiration is, that we understand so much of astronomy as we do. That an animal confined to the surface of one of the planets; bearing a less proportion to it, than the smallest microscopic insect does to the plant it lives upon; that this little, busy,

inquisitive creature, by the use of senses which were given to it for its domestic necessities, and by means of the assistance of those senses which it has had the art to procure, should have been enabled to observe the whole system of worlds to which its own belongs; the changes of place of the immense globes which compose it; and with such accuracy, as to mark out, beforehand, the situation in the heavens in which they will be found at any future point of time; and that these bodies, after sailing through regions of void and trackless space, should arrive at the place where they were expected, not within a minute, but within a few seconds of a minute, of the time prefixed and predicted: all this is wonderful, whether we refer our admiration to the constancy of the heavenly motions themselves, or to the perspicacity and precision with which they have been noticed by mankind. Nor is this the whole, nor indeed, the chief part, of what astronomy teaches. By bringing reason to bear upon observation, (the acutest reasoning upon the exactest observation,) the astronomer has been able, out of the confusion, (for such it is) under which the motions of the heavenly bodies present themselves to the eye of a mere gazer upon the skies, to elicit their order and their real paths.

Our knowledge therefore of astronomy is admirable though imperfect: and, amidst the confessed desiderata and desideranda, which impede our investigation of the wisdom of the Deity, in these the grandest of his works, there are to be found, in the phenomena, ascertained circumstances and laws, sufficient to indicate an intellectual agency in three of its principal operations, viz. in choosing, in determining, in regulating; in *choosing*, out of a boundless variety of suppositions which were equally possible, that which is beneficial; in *determining*, what, left to itself, had a thousand chances against conveniency, for

one in its favour; in *regulating* subjects, as to quantity and degree, which, by their nature, were unlimited with respect to either. It will be our business to offer, under each of these heads, a few instances, such as best admit of a popular explication.

I. Amongst proofs of choice, one is, fixing the source of light and heat in the *centre* of the system. The sun is ignited and luminous; the planets which move round him, cold and dark. There seems to be no antecedent necessity for this order. The sun might have been an opaque mass: some one, or two, or more, or any, or all, of the planets, globes of fire. There is nothing in the nature of the heavenly bodies, which requires that those which are stationary should be on fire, that those which move should be cold; for, in fact, comets are bodies on fire, yet revolve round a centre: nor does this order obtain between the primary planets and their secondaries, which are all opaque. When we consider, therefore, that the sun is one; that the planets going round it are, at least, seven; that it is indifferent to their nature which are luminous and which are opaque; and also, in what order with respect to each other, these two kinds of bodies are disposed; we may judge of the improbability of the present arrangement taking place by chance.

If, by way of accounting for the state in which we find the solar system, it be alleged (and this is one amongst the guesses of those who reject an intelligent Creator) that the planets themselves are only cooled or cooling masses, and were once, like the sun, many thousand times hotter than red hot iron; then it follows, that the sun also himself must be in his progress towards growing cold; which puts an end to the possibility of his having existed, as he is, from eternity. This consequence arises out of the hypothesis with still more certainty, if

we make a part of it, what the philosphers, who maintain it, have usually taught, that the planets were originally masses of matter struck off, in a state of fusion, from the body of the sun, by the percussion of a comet, or by a shock from some other cause with which we are not acquainted: for, if these masses, partaking of the nature and substance of the sun's body, have in process of time lost their heat, that body itself, in time likewise, no matter in how much longer time, must lose its heat also; and therefore be incapable of an enternal duration in the state in which we see it, either for the time to come, or the time past.

The preference of the present to any other mode of distributing luminous and opaque bodies I take to be evident. It requires more astronomy than I am able to lay before the reader, to show, in its particulars, what would be the effect to the system, of a dark body at the centre, and of one of the planets being luminous: but I think it manifest, without either plates or calculation, first, that, supposing the necessary proportion of magnitude between the central and the revolving bodies to be preserved, the ignited planet would not be sufficient to illuminate and warm the rest of the system; secondly, that its light and heat would be imparted to the other planets, much more irregularly than light and heat are now received from the sun.

(*) II. Another thing, in which a choice appears to be exercised; and in which, amongst the possibilities out of which the choice was to be made, the number of those which were wrong, bore an infinite proportion to the number of those which were right, is in what geometricians call the *axis of rotation*. This matter I will endeavour to explain. The earth, it is well known, is not an exact globe, but an oblate spheroid, something like an orange.

Now the axes of rotation, or the diameters upon which such a body may be made to turn round, are as many as can be drawn through its centre to opposite points upon its whole surface: but of these axes none are *permanent*, except either its shortest diameter, i. e. that which passes through the heart of the orange from the place where the stalk is inserted into it, and which is but one; or its longest diameters, at right angles with the former, which must all terminate in the single circumference which goes round the thickest part of the orange. This shortest diameter is that upon which in fact the earth turns; and it is, as the reader sees, what it ought to be, a permanent axis: whereas, had blind chance, had a casual impulse, had a stroke or push at random, set the earth a-spinning, the odds were infinite, but that they had sent it round upon a wrong axis. And what would have been the consequence? The difference between a permanent axis and another axis is this. When a spheroid in a state of rotatory motion gets upon a permanent axis, it keeps there; it remains steady and faithful to its position; its poles preserve their direction with respect to the plane and to the centre of its orbit: but, whilst it turns upon an axis which is *not* permanent, (and the number of those, we have seen, infinitely exceeds the number of the other,) it is always liable to shift and vacillate from one axis to another, with a correspoding change in the inclination of its poles. Therefore, if a planet once set off revolving upon any other than its shortest, or one of its longest axes, the poles on its surface would keep perpetually changing, and it never would attain a permanent axis of rotation. The effect of this unfixedness and instability would be, that the equatorial parts of the earth might become the polar, or the polar the equitorial; to the utter destruction of plants and animals, which are not capable of interchan-

ging their situations, but are respectively adapted to their own. As to ourselves, instead of rejoicing in our temperate zone, and annually preparing for the moderate vicissitude, or rather the agreeable succession of seasons, which we experience and expect, we might come to be locked up in the ice and darkness of the arctic circle, with bodies, neither inured to its rigors, nor provided with shelter or defence against them. Nor would it be much better, if the trepidation of our pole, taking an opposite course, should place us under the heats of a vertical sun. But, if it would fare so ill with the human inhabitant, who can live under greater varieties of latitude than any other animal, still more noxious would this translation of climate have proved to life in the rest of the creation; and, most perhaps of all, in plants. The habitable earth, and its beautiful variety, might have been destroyed, by a simple mischance in the axis of rotation.

(*) III. All this however proceeds upon a supposition of the earth having been formed at first an oblate spheriod. There is another supposition; and, perhaps, our limited information will not enable us to decide between them. The second supposition is, that the earth, being a mixed mass, somewhat fluid, took, as it might do, its present form, by the joint action of the mutual gravitation of its parts and its rotatory motion. This, as we have said, is a point in the history of the earth, which our observations are not sufficient to determine. For a very small depth below the surface (but extremely small, less, perhaps, than an eight thousandth part, compared with the depth of the centre) we find vestiges of ancient fluidity. But this fluidity must have gone down many hundred times further than we can penetrate, to enable the earth to take its present oblate form; and, whether any traces of this kind exist to that depth, we are ignorant. Calculations were

made a few years ago of the mean density of the earth, by comparing the force of its attraction with the force of attraction of a rock of granite, the bulk of which could be ascertained: and the upshot of the calculation was, that the earth upon an average, through its whole sphere, has twice the density of granite, or about five times that of water. Therefore it cannot be a hollow shell, as some have formerly supposed: nor can its internal parts be occupied by central fire, or by water. The solid parts must greatly exceed the fluid parts; and the probability is, that it is a solid mass throughout, composed of substances, more ponderous the deeper we go. Nevertheless, we may consider the present face of the earth to have originated from the revolution of a sphere, covered with a surface of a compound mixture; the fluid and solid parts separating, as the surface became quiescent. Here then comes in the *moderating* hand of the Creator. If the water had exceeded its present proportion, even but by a trifling quantity compared with the whole globe, all the land would have been covered: had there been much less than there is, there would not have been enough to fertilize the continent. Had the exsication been progressive, such as we may suppose to have been produced by an evaporating heat, how came it to stop at the point at which we see it? Why did it not stop sooner; why at all? The mandate of the Deity will account for this: nothing else will.

VI. Of centripetal forces. By virtue of the simplest law that can be imagined, viz. that a body *continues* in the state in which it is, whether of motion or rest; and, if in motion, goes on in the line in which it was proceeding, and with the same velocity, *unless* there be some cause for change: by virtue, I say, of this law, it comes to pass (what may appear to be a strange consequence) that cases arise, in which attraction, incessantly drawing

a body towards a centre, never brings, nor ever will bring, the body to that centre, but keep it in eternal circulation round it. If it were possible to fire off a cannon ball with a velocity of five miles in a second, and the resistance of the air could be taken away, the cannon ball would for ever wheel round the earth, instead of falling down upon it. This is the principle which sustains the heavenly motions. The Deity having appointed this law to matter, than which, as we have said before, no law could be more simple, has turned it to a wonderful account in constructing planetary systems.

The actuating cause in these systems, is an attraction which varies reciprocally as the square of the distance; that is, at double the distance, has a quarter of the force; at half the distance, four times the strength; and so on. Now, concerning this law of variation, we have three things to observe; first, that attraction, for any thing we know about it, was just as capable of one law of variation as of another: secondly; that, out of an infinite number of possible laws, those which were admissible for the purpose of supporting the heavenly motions, lay within certain narrow limits: thirdly; that of the admissible laws, or those which come within the limits prescribed, the law that actually prevails is the most beneficial. So far as these propositions can be made out, we may be said, I think, to prove choice and *regulation;* choice, out of boundless variety; and regulation, of that which, by its own nature, was, in respect of the property regulated, indifferent and indefinite.

I. First, then, attraction, for any thing we know about it, was originally indifferent to all laws of variation depending upon change of distance, i. e. just as susceptible of one law as of another. It might have been the same at all distances. It might have increased as the distance in-

creased. Or it might have diminished with the increase of the distance, yet in ten thousand different proportions from the present. It might have followed no stated law at all. If attraction be, what Cotes, with many other Newtonians have thought it, a primordial property of matter, not dependent upon, or traceable to, any material cause, then, by the very nature and definition of a primordial property, it stood indifferent to all laws. If it be the agency of something immaterial, then also, for any thing we know of it, it was indifferent to all laws. If the revolution of bodies round a centre depend upon vortices, neither are these limited to one law more than another.

There is, I know, an account given of attraction, which should seem, in its very cause, to assign to it the law, which we find it to observe, and which, therefore, makes that law, a law, not of choice, but of necessity: and it is the account, which ascribes attraction to an *emanation* from the attracting body. It is probable, that the influence of such an emanation will be proportioned to the spissitude of the rays, of which it is composed: which spissitude, supposing the rays to issue in right lines on all sides from a point, will be reciprocally as the square of the distance. The mathematics of this solution we do not call in question: the question with us is, whether there be any sufficient reason to believe, that attraction is produced by an emanation. For my part, I am totally at a loss to comprehend, how particles streaming *from* a centre, should draw a body *towards* it. The impulse, if impulse it be, is all the other way. Nor shall we find less difficulty in conceiving, a conflux of particles, incessantly flowing to a centre, and carrying down all bodies along with it, that centre also itself being in a state of rapid motion through absolute space; for, by what source is the

stream fed, or what becomes of the accumulation? Add to which, that it seems to imply a contrariety of properties, to suppose an ethereal fluid to *act*, but not to *resist*; powerful enough to carry down bodies with great force towards a centre, yet, inconsistently with the nature of inert matter, powerless and perfectly yielding with respect to the motions which result from the projectile impulse. By calculations drawn from ancient notices of eclipses of the moon, we can prove, that, if such a fluid exist at all, its resistance has had no sensible effect upon the moon's motion for two thousand five hundred years. The truth is, except this one circumstance of the variation of the attracting force at different distances agreeing with the variation of the spissitude, there is no reason whatever to support the hypothesis of an emanation; and, as it seems to me, almost insuperable reasons against it.

(*) II. Our second proposition is, that, whilst the possible laws of variation were infinite, the *admissible* laws, or the laws compatible with the preservation of the system, lay within narrow limits. If the attracting force had varied according to any *direct* law of the distance, let it have been what it would, great destruction and confusion would have taken place. The direct simple proportion of the distance would, it is true, have produced an ellipse; but the perturbing forces would have acted with so much advantage, as to be continually changing the dimensions of the ellipse, in a manner inconsistent with our terrestrial creation. For instance; if the planet Saturn, so large and so remote, had attracted the earth, both in proportion to the quantity of matter contained in it, which it does; and also in any proportion to its distance, i. e. if it had pulled the harder for being the further off, (instead of the reverse of it,) it would have dragged the globe which we inhabit out of its course, and have perplexed its motions,

to a degree incompatible with our security, our enjoyments, and probably our existence. Of the *inverse* laws, if the centripetal force had changed as the cube of the distance, or in any higher proportion, that is, (for I speak to the unlearned,) if, at double the distance, the attractive force had been diminished to an eighth part, or to less than that, the consequence would have been, that the planets, if they once began to approach the sun, would have fallen into his body; if they once, though by ever so little, increased their distance from the centre, would for ever have receded from it. The laws therefore of attraction, by which a system of revolving bodies could be upheld in their motions, lie within narrow limits, compared with the possible laws. I much underrate the restriction, when I say, that in a scale of a mile they are confined to an inch. All direct ratios of the distance are excluded, on account of danger from perturbing forces: all reciprocal ratios, except what lie beneath the cube of the distance, by the demonstrable consequence, that every, the least change of distance, would, under the operation of such laws, have been fatal to the repose and order of the system. We do not know, that is, we seldom reflect, how interested we are in this matter. Small irregularities may be endured; but, changes within these limits being allowed for, the permanency of our ellipse is a question of life and death to our whole sensitive world.

(*) III. That the subsisting law of attraction falls within the limits which utility requires, when these limits bear so small a proportion to the range of possibilities, upon which chance might equally have cast it, is not, with any appearance of reason, to be accounted for, by any other cause than a regulation proceeding from a designing mind. But our next proposition carries the matter somewhat further. We say, in the third place, that, out of the

different laws which lie within the limits of admissible laws, the *best* is made choice of; that there are advantages in this particular law which cannot be demonstrated to belong to any other law; and concerning some of which, it can be demonstrated that they do not belong to any other.

(*) 1. Whilst this law prevails between each particle of matter, the *united* attraction of a sphere, composed of that matter, observes the same law. This property of the law is necessary, to render it applicable to a system composed of spheres, but it is a property which belongs to no other law of attraction that is admissible. The law of variation of the united attraction is in no other case the same as the law of attraction of each particle, one case excepted, and that is of the attraction varying directly as the distance; the inconveniency of which law in other respects we have already noticed.

(*) 2. Under the subsisting law, the *apsides*, the returning points, or points of greatest and least distance from the centre, are *quiescent*, and, therefore, the body moves every revolution in exactly the same path relative to the attracting centre: which it would not do, under any other law whatever except that of the direct ratio of the distance, which we have seen to be objectionable. The planetary system required that the law of attraction should be a law which gave an orbit returning into itself. Now, out of an infinite number of laws, admissible and inadmissible, out of a vast variety even of admissible laws, there are few, except the actual law, which would do this. Here then is choice.

(*) 3. All systems must be liable to *perturbations*. And therefore to guard against these perturbations, or rather to guard against their running to destructive lengths, is perhaps the strongest evidence of care and foresight that

can be given. Now we are able to demonstrate of our law of attraction, what can be demonstrated of no other, and what qualifies the dangers which arise from cross but unavoidable influences, that the action of the parts of our system upon one another will not cause permanently increasing irregularities, but merely periodical ones: that is, they will come to a limit, and then go back again. This we can demonstrate only of a system, in which the following properties concur, viz. that the force shall be inversely as the square of the distance; the masses of the revolving bodies small, compared with that of the body at the centre; the orbits not much inclined to one another; and their eccentricity little. In such a system the grand points are secure. The mean distances and periodic times, upon which depend our temperature, and the regularity of our year, are constant. The eccentricities, it is true, will still vary, but so slowly, and to so small an extent, as to produce no inconveniency from fluctuation of temperature and season. The same as to the obliquity of the planes of the orbits. For instance, the inclination of the ecliptic to the equator will never change above two degrees, (out of ninety,) and that will require many thousand years in performing.

It has been rightly also remarked, that, if the great planets, Jupiter and Saturn, had moved in lower spheres, their influences would have had much more effect as to disturbing the planetary motions than they now have. While they revolve at so great distances from the rest, they act almost equally on the sun and on the inferior planets, which has nearly the same consequence as not acting at all upon either.

If it be said that the planets might have been sent round the sun in exact circles, in which case, no change

of distance from the centre taking place, the law of variation of the attracting power would have never come in question; one law would have served as well as another; an answer to the scheme may be drawn from the consideration of these same perturbing forces. The system retaining in other respects its present constitution, though the planets had been at first sent round in exact circular orbits, they could not have kept them: and if the law of attraction had not been what it is, (or, at least, if the prevailing law had transgressed the limits above assigned,) every evagation would have been fatal; the planet once drawn, as drawn it necessarily must have been out of its course, would have wandered in endless error.

(*) V. What we have seen in the law of the centripetal force, viz. a choice guided by views of utility, and a choice of one law out of thousands which might equally have taken place, we see no less in the *figures* of the planetary orbits. It was not enough to fix the law of the centripetal force, though by the wisest choice, for, even under that law, it was still competent to the planets to have moved in paths possessing so great a degree of eccentricity, as, in the course of every revolution, to be brought very near to the sun, and carried away to immense distances from him. The comets actually move in orbits of this sort: and, had the planets done so, instead of going round in orbits nearly circular, the change from one extremity of temperature to another must, in ours at least, have destroyed every animal and plant upon its surface. Now, the distance from the centre at which a planet sets off, and the absolute force of attraction at that distance, being fixed, the figure of his orbit, its being a circle, or nearer to, or further off from, a circle, viz. a rounder or a longer oval, depends upon two things, the velocity with which, and the direction in which, the pla-

net is projected. And these, in order to produce a right result, must be both brought within certain narrow limits. One, and only one, velocity, united with one, and only one, direction, will produce a perfect circle. And the velocity must be near to this velocity, and the direction also near to this direction, to produce orbits, such as the planetary orbits are, nearly circular; that is, ellipses, with small eccentricities. The velocity and the direction must *both* be right. If the velocity be wrong, no direction will cure the error; if the direction be in any considerable degree oblique, no velocity will produce the orbit required. Take for example the attraction of gravity at the surface of the earth. The force of that attraction being what it is, out of all the degrees of velocity, swift and slow, with which a ball might be shot off, none would answer the purpose of which we are speaking but what was nearly that of five miles in a second. If it were less than that, the body would not get round at all, but would come to the ground: if it were in any considerable degree more than that, the body would take one of those eccentric courses, those long ellipses, of which we have noticed the inconveniency. If the velocity reached the rate of seven miles in a second, or went beyond that, the ball would fly off from the earth, and never be heard of more. In like manner with respect to the *direction;* out of the innumerable angles in which the ball might be sent off, I mean angles formed with a line drawn to the centre, none would serve but what was nearly a right one; out of the various directions in which the cannon might be pointed, upwards and downwards, every one would fail, but what was exactly or nearly horizontal. The same thing holds true of the planets; of our own amongst the rest. We are entitled, therefore, to ask, and to urge the question, Why did the projectile velocity, and projectile direction of the earth happen to be

nearly those which would retain it in a *circular* form? Why not one of the infinite number of velocities, one of the infinite number of directions, which would have made it approach much nearer to, or recede much further from, the sun?

The planets going round, all in the same direction, and all nearly in the same plane, afforded to Buffon a ground for asserting, that they had all been shivered from the sun by the same stroke of a comet, and by that stroke projected into their present orbits. Now, beside that this is to attribute to chance the fortunate concurrence of velocity and direction which we have been here noticing, the hypothesis, as I apprehend, is inconsistent with the physical laws by which the heavenly motions are governed. If the planets were struck off from the surface of the sun, they would return to the surface of the sun again. Or, if, to get rid of this difficulty, we suppose, that the same violent blow, which shattered the sun's surface and separated large fragments from it, pushed also the sun himself out of his place; a question of no less difficulty presents itself, namely, when once put into motion, what should *stop* him. The hypothesis is also contradicted by the vast difference which subsists between the *diameters* of the planetary orbits. The distance of Saturn from the sun (to say nothing of the Georgium Sidus) is nearly five-and-twenty times that of Mercury; a disparity, which it seems impossible to reconcile with Buffon's scheme. Bodies starting from the same place, with whatever difference of direction or velocity they set off, could not have been found at these different distances from the centre, still retaining their nearly circular orbits. They must have been carried to their proper distances before they were projected.*

* "If we suppose the matter of the system to be accumulated in the centre by its gravity, *no* mechanical principles, with the assistance of this

To conclude: In astronomy, the great thing is to raise the imagination to the subject, and that oftentimes in opposition to the impression made upon the senses. An allusion, for example, must be got over, arising from the distance at which we view the heavenly bodies, viz. the apparent *slowness* of their motions. The moon shall take some hours in getting half a yard from a star which it touched. A motion so deliberate, we may think easily guided. But what is the fact? The moon, in fact, is, all this while, driving through the heavens, at the rate of considerably more than two thousand miles in an hour; which is more than double of that, with which a ball is shot off from the mouth of a cannon. Yet is this prodigious rapidity as much under government, as if the planet proceeded ever so slowly, or were conducted in its course inch by inch. It is also difficult to bring the imagination to conceive (what yet, to judge tolerably of the matter, it is necessary to conceive) how *loose*, if we may so express it, the heavenly bodies are. Enormous globes, held by nothing, confined by nothing, are turned into free and boundless space, each to seek its course by the virtue of an invisible principle; but a principle, one, common, and the same, in all; and ascertainable. To preserve such bodies from being lost, from running together in heaps, from hindering and distracting one another's motions, in a degree

power of gravity, could separate the vast mass into such parts as the sun and planets; and, after carrying them to their different distances, project them in their several directions, preserving still the equality of action and re-action, or the state of the centre of gravity of the system. Such an exquisite structure of things could only arise from the contrivance and powerful influences of an intelligent, free, and most potent agent. The same powers, therefore, which, at present, govern the material universe, and conduct its various motions, are very different from those which were necessary, to have produced it from nothing, or to have disposed it in the admirable form, in which it now proceeds."—*Maclaurin's Account of Newton's Phil.* p. 407. ed. 3.

inconsistent with any continuing order; i. e. to cause them to form planetary systems, systems that, when formed, can be upheld, and, most especially, systems accommodated to the organized and sensitive natures which the planets sustain, as we know to be the case, where alone we can know what the case is, upon our earth: all this requires an intelligent interposition, because it can be demonstrated concerning it, that it requires an adjustment of force, distance, direction, and velocity, out of the reach of chance to have produced; an adjustment, in its view to utility similar to that which we see in ten thousand subjects of nature which are nearer to us, but in power, and in the extent of space through which that power is exerted, stupendous.

But many of the heavenly bodies, as the sun and fixed stars, are *stationary*. Their rest must be the effect of an absence or of an equilibrium of attractions. It proves also that a projectile impulse was originally given to some of the heavenly bodies, and not to others. But further; if attraction act at all distances, there can be only one quiescent centre of gravity in the universe: and all bodies whatever must be approaching this centre, or revolving round it. According to the first of these suppositions, if the duration of the world had been long enough to allow of it, all its parts, all the great bodies of which it is composed, must have been gathered together in a heap round this point. No changes, however, which have been observed, afford us the smallest reason for believing that either the one supposition or the other is true: and then it will follow, that attraction itself is controlled or suspended by a superior agent; that there is a power above the highest of the powers of material nature; a will which restrains and circumscribes the operations of the most extensive.

CHAPTER XXIII.

OF THE PERSONALITY OF THE DEITY.

CONTRIVANCE, if established, appears to me to prove every thing which we wish to prove. Amongst other things it proves the *personality* of the Deity, as distinguished from what is sometimes called nature, sometimes called a principle: which terms, in the mouths of those who use them philosophically, seem to be intended, to admit and to express an efficacy, but to exclude and to deny a personal agent. Now that which can contrive, which can design, must be a person. These capacities constitute personality, for they imply consciousness, and thought. They require that which can perceive an end or purpose; as well as the power of providing means, and of directing them to their end.* They require a centre in which perceptions unite, and from which volitions flow; which is mind. The acts of a mind prove the existence of a mind: and in whatever a mind resides is a person. The seat of intellect is a person. We have no authority to limit the properties of mind, to any particular corporeal form, or any particular circumscription of space. These properties subsist, in created nature, under a great variety of sensible forms. Also, every animated being has its *sensorium*, that is, a certain portion of space, within which perception and volition are exerted. This sphere may be enlarged to an indefinite extent; may comprehend the universe; and, being so imagined, may serve to furnish us with as good a notion, as we are capable of forming, of the *immensity* of the divine nature, i. e. of a

* Priestley's Letters to a Philosophical Unbeliever, p. 153, ed. 2.

Being, infinite, as well in essence, as in power; yet nevertheless a person.

"No man hath seen God at any time." And this, I believe, makes the great difficulty. Now it is a difficulty, which chiefly arises from our not duly estimating the state of our faculties. The Deity, it is true is the object of none of our senses: but reflect what limited capacities animal senses are. Many animals seem to have but one sense, or perhaps two at the most, touch and taste. Ought such an animal to conclude against the existence of smells, sounds, and colours? To another species is given the sense of smelling. This is an advance in the knowledge of the powers and properties of nature: but if this favoured animal should infer from its superiority over the class last described, that it perceived every thing which was perceptible in nature it is known to us, though perhaps not suspected by the animal itself, that it proceeded upon a false and presumptuous estimate of its faculties. To another is added the sense of hearing; which lets in a class of sensations entirely unconceived by the animal before spoken of; not only distinct, but remote from any which *it* had ever experienced, and greatly superior to them. Yet this last animal has no more ground for believing, that its senses comprehend all things, and all properties of things which exist, than might have been claimed by the tribes of animals beneath it: for we know, that it is still possible to possess another sense, that of sight, which shall disclose to the percipient a new world. This fifth sense makes the animal what the human animal is: but to infer that possibility stops here; that either this fifth sense is the last sense, or that the five comprehended all existence, is just as unwarrantable a conclusion, as that which might have been made by any of the different species which possessed fewer or even by that, if such there be, which possessed

only one. The conclusion of the one sense animal, and the conclusion of the five sense animal stand upon the same authority. There may be more and other senses than those which we have. There may be senses suited to the perception of the powers, properties and substance of spirits. These may belong to higher orders of rational agents; for there is not the smallest reason for supposing that we are the highest, or that the scale of creation stops with us.

The great *energies* of nature are known to us only by their effects. The substances which produce them, are as much concealed from our senses as the divine essence itself. *Gravitation*, though constantly present, though constantly exerting its influence, though every where around us, near us, and within us; though diffused throughout all space, and penetrating the texture of all bodies with which we are acquainted, depends, if upon a fluid, upon a fluid, which, though both powerful and universal in its operation, is no object of sense to us; if upon any other kind of substance or action, upon a substance and action from which *we* receive no distinguishable impressions. Is it then to be wondered at, that it should, in some measure, be the same with the divine nature?

Of this however we are certain, that, whatever the Deity be, neither the *universe*, nor any part of it which we see, can be he. The universe itself is merely a collective name: its parts are all which are real; or which are *things*. Now inert matter is out of the question; and organized substances include marks of contrivance. But whatever includes marks of contrivance, whatever, in its constitution, testifies design, necessarily carries us to something beyond itself, to some other being, to a designer prior to, and out of, itself. No animal, for instance,

can have contrived its own limbs and senses; can have been the author to itself of the design with which they were constructed. That supposition involves all the absurdity of self-creation, i. e. of acting without existing. Nothing can be God, which is ordered by a wisdom and a will, which itself is void of: which is indebted for any of its properties to contrivance *ab extra*. The *not* having that in his nature which requires the exertion of another prior being, (which property is sometimes called self-sufficiency, and sometimes self-comprehension,) appertains to the Deity, as his essential distinction, and removes his nature from that of all things which we see. Which consideration contains the answer to a question that has sometimes been asked, namely; Why, since something or other must have existed from eternity, may not the present universe be that something? The contrivance, perceived in it, proves that to be impossible. Nothing contrived, can, in a strict and proper sense, be eternal, forasmuch as the contriver must have existed before the contrivance.

Wherever we see marks of contrivance, we are led for its cause to an *intelligent* author. And this transition of the understanding is founded upon uniform experience. We see intelligence constantly contriving, that is, we see intelligence constantly producing effects, marked and distinguished by certain properties; not certain particular properties, but by a kind and class of properties, such as relation to an end, relation of parts to one another, and to a common purpose. We see, wherever we are witnesses to the actual formation of things, nothing except intelligence producing effects so marked and distinguished. Furnished with this experience, we view the productions of nature. We observe *them* also marked and distinguished in the same manner. We wish to account for their origin. Our experience suggests a cause perfectly adequate

to this account. No experience, no single instance or example, can be offered in favour of any other. In this cause therefore we ought to rest: in this cause the common sense of mankind has in fact rested, because it agrees with that, which, in all cases, is the foundation of knowledge, the undeviating course of their experience. The reasoning is the same, as that, by which we conclude any ancient appearances to have been the effects of volcanos or inundations, namely, because they resemble the effects which fire and water produce before our eyes; and because we have never known these effects to result from any other operation. And this resemblance may subsist in so many circumstances, as not to leave us under the smallest doubt in forming our opinion. Men are not deceived by this reasoning; for whenever it happens, as it sometimes does happen, that the truth comes to be known by direct information, it turns out to be what was expected. In like manner, and upon the same foundation, (which in truth is that of experience,) we conclude that the works of nature proceed from intelligence and design, because, in the properties of relation to a purpose, subserviency to an use, they resemble what intelligence and design are constantly producing, and what nothing except intelligence and design ever produce at all. Of every argument, which would raise a question as to the safety of this reasoning, it may be observed, that, if such argument be listened to, it leads to the inference, not only that the present order of nature is insufficient to prove the existence of an intelligent Creator, but that no imaginable order would be sufficient to prove it; that *no* contrivance, were it ever so mechanical, ever so precise, ever so clear, ever so perfectly like those which we ourselves employ, would support this conclusion. A doctrine, to which, I conceive, no sound mind can assent.

The force, however, of the reasoning, is sometimes sunk by our taking up with mere names. We have already noticed,* and we must here notice again, the misapalication of the term "law," and the mistake concerning the idea which that term expresses in physics, whenever such idea is made to take the place of power, and still more of an intelligent power, and, as such, to be assigned for the cause of any thing, or of any property of any thing, that exists. This is what we are secretly apt to do when we speak of organized bodies (plants, for instance, or animals) owing their production, their form, their growth, their qualities, their beauty, their use, to any law or laws of nature: and when we are contented to sit down with that answer to our inquiries concerning them. I say once more, that it is a perversion of language to assign any law as the efficient, operative cause of any thing. A law presupposes an agent, for it is only the mode according to which an agent proceeds: it implies a power, for it is the order according to which that power acts. Without this agent, without this power, which are both distinct from itself, the "law" does nothing; is nothing.

What has been said concerning "law," holds true of *mechanism*. Mechanism is not itself power. Mechanism without power, can do nothing. Let a watch be contrived and constructed ever so ingeniously; be its parts ever so many, ever so complicated, ever so finely wrought, or artificially put together, it cannot *go* without a weight or spring, i. e. without a force independent of, and ulterior to its mechanism. The spring acting at the centre, will produce different motions and different results, according to the variety of the intermediate mechanism. One and the self-same spring, acting in one and the same manner, viz. by simply expanding itself, may be the cause of a hun-

dred different, and all useful movements, if a hundred different and well devised sets of wheels be placed between it and the final effect, e. g. may point out the hour of the day, the day of the month, the age of the moon, the position of the planets, the cycle of the years, and many other serviceable notices; and these movements may fulfil their purposes with more or less perfection, according as the mechanism is better or worse contrived, or better or worse executed, or in a better or worse state of repair: *but, in all cases, it is necessary that the spring act at the centre.* The course of our reasoning upon such a subject would be this. By inspecting the watch, even when standing still, we get a proof of contrivance, and of a contriving mind, having been employed about it. In the form and obvious relation of its parts we see enough to convince us of this. If we pull the works in pieces, for the purpose of a closer examination, we are still more fully convinced. But, when we see the watch *going*, we see proof of another point, viz. that there is a power somewhere, and somehow or other, applied to it; a power in action; that there is more in the subject than the mere wheels of the machine; that there is a secret spring or a gravitating plummet; in a word, that there is force and energy, as well as mechanism.

So, then, the watch in motion establishes to the observer two conclusions: one; that thought, contrivance, and design, have been employed in the forming, proportioning, and arranging of its parts; and that, whoever, or wherever he be, or were, such a contriver there is, or was: the other; that force or power, distinct from mechanism, is, at this present time, acting upon it. If I saw a hand-mill, even at rest, I should see contrivance; but, if I saw it grinding, I should be assured that a hand was at the

windlass, though in another room. It is the same in nature. In the works of nature we trace mechanism; and this alone proves contrivance: but living, active, moving, productive nature, proves also the exertion of a power at the centre; for, wherever the power resides, may be denominated the centre.

The intervention and disposition of what are called "*second causes*" fall under the same observation. This disposition is or is not mechanism, according as we can or cannot trace it by our senses, and means of examination. That is all the difference there is; and it is a difference which respects our faculties, not the things themselves. Now where the order of second causes is mechanical, what is here said of mechanism strictly applies to it. But it would be always mechanism, (natural chymistry, for instance, would be mechanism,) if our senses were acute enough to descry it. Neither mechanism, therefore, in the works of nature, nor the intervention of what are called second causes, (for I think that they are the same thing,) excuse the necessity of an agent distinct from both.

If, in tracing these causes, it be said, that we find certain general properties of matter, which have nothing in them that bespeaks intelligence, I answer, that, still, the *managing* of these properties, the pointing and directing them to the uses which we see made of them, demands intelligence in the highest degree. For example, suppose animal secretions to be elective attractions, and that such and such attractions universally belong to such and such substances; in all which there is no intellect concerned; still the choice and collocation of these substances, the fixing upon right substances and disposing them in right places must be an act of intelligence. What mischief would follow, were there a single transposition of the se-

cretory organs; a single mistake in arranging the glands which compose them?

There may be many second causes, and many courses of second causes, one behind another, between what we observe of nature, and the Deity; but there must be intelligence somewhere; there must be more in nature than what we see; and, amongst the things unseen, there must be an intelligent, designing, author. The philosopher beholds with astonishment the production of things around him. Unconscious particles of matter take their stations, and severally range themselves in an order, so as to become collectively plants or animals, i. e. organized bodies with parts bearing strict and evident relation to one another, and to the utility of the whole: and it should seem that these particles could not move in any other way than as they do, for they testify not the smallest sign of choice, or liberty, or discretion. There may be plastic natures, particular intelligent beings, guiding these motions in each case: or they may be the result of trains of mechanical dispositions, fixed beforehand by an intelligent appointment, and kept in action by a power at the centre. But in either case; there must be intelligence.

The minds of most men are fond of what they call a *principle*, and of the appearance of simplicity, in accounting for phenomena. Yet this principle, this simplicity, is sometimes nothing more than in the *name;* which name, comprises, perhaps, under it a diversified, multifarious, or progressive operation, distinguishable into parts. The power, in organized bodies, of producing bodies like themselves, is one of these principles. Give a philosopher this, and he can get on. But he does not reflect, what this principle, (if such he choose to call it,) what this mode of production requires; how much it presupposes; what an apparatus of instruments, some of which are strictly mech-

nical, is necessary to its success; what a train it includes of operations and changes, one succeeding another, one related to another, one ministering to another; all advancing, by intermediate, and, frequently, by sensible steps, to their ultimate result. Yet, because the whole of this complicated action is wrapped up in a single term, *generation*, we are to set it down as an elementary principle; and to suppose, that, when we have resolved the things which we see into this principle, we have sufficiently accounted for their origin, without the necessity of a designing, intelligent Creator. The truth is, generation is not a principle, but a *process*. We might as well call the casting of metals a principle: we might, so far as appears to me, as well call spinning and weaving principles: and then, referring the texture of cloths, the fabric of muslins and callicoes, the patterns of diapers and damasks, to these as principles, pretend to dispense with intention, thought, and contrivance, on the part of the artist: or to dispense, indeed, with the necessity of any artist at all either in the manufactory of the article, or in the fabrication of the machinery by which the manufactory was carried on.

And, after all, how, or in what sense, is it true, that animals produce their *like?* A butterfly, with a proboscis instead of a mouth, with four wings and six legs, produces a hairy caterpillar, with jaws and teeth, and fourteen feet. A frog produces a tadpole. A black beetle, with gauze wings and a crusty covering, produces a white, smooth, soft worm: an ephemeron fly, a cod-bait maggot. These, by a progress through different stages of life, and action, and enjoyment, (and, in each state, provided with implements and organs appropriated to the temporary nature which they bear,) arrive at last at the form and fashion of the parent animal. But all this is process, not principle;

and proves, moreover, that the property of animated bodies of producing their like, belongs to them, not as a primordial property, not by any blind necessity in the nature of things, but as the effect of economy, wisdom, and design; because the property itself, assumes diversities, and submits to deviations, dictated by intelligible utilities, and serving distinct purposes of animal happiness.

The opinion, which would consider "generation" as a *principle* in nature; and which would assign this principle as the cause, or endeavour to satisfy our minds with such a cause, of the existence of organized bodies, is confuted, in my judgment, not only by every mark of contrivance discoverable in those bodies, for which it gives us no contriver, offers no account, whatever; but also by the further consideration, that things generated possess a clear relation to things *not* generated. If it were merely one part of a generated body bearing a relation to another part of the same body, as the mouth of an animal to the throat, the throat to the stomach, the stomach to the intestines, those to the recruiting of the blood, and, by means of the blood, to the nourishment of the whole frame: or if it were only one generated body, leaving a relation to another generated body, as the sexes of the same species to each other, animals of prey to their prey, herbivorous and graminivorous animals to the plants or seeds upon which they feed, it might be contended, that the whole of this correspondency was attributable to generation, the common origin from which these substances proceeded. But what shall we say to agreements which exist between things generated and things *not generated?* Can it be doubted, was it ever doubted, but that the *lungs* of animals bear a relation to the *air*, as a permanently elastic fluid? They act in it and by it: they cannot act without it. Now, if generation produced the animal, it

did not produce the air; yet their properties correspond. The *eye* is made for *light*, and light for the eye. The eye would be of no use without light, and light perhaps of little without eyes: yet one is produced by generation; the other not. The *ear* depends upon *undulations* of air. Here are two sets of motions; first, of the pulses of the air; secondly, of the drum, bones, and nerves of the ear; sets of motions bearing an evident reference to each other: yet the one, and the apparatus for the one, produced by the intervention of generation; the other altogether independent of it.

If it be said, that the air, the light, the elements, the world itself, is *generated*, I answer, that I do not comprehend the proposition. If the term mean any thing, similar to what it means, when applied to plants or animals, the proposition is certainly without proof; and, I think, draws as near to absurdity, as any proposition can do, which does not include a contradiction in its terms. I am at a loss to conceive, how the formation of the world can be compared to the generation of an animal. If the term generation signify something quite different from what it signifies upon ordinary occasions, it may, by the same latitude, signify any thing. In which case a word or phrase taken from the language of Otaheite, would convey as much theory concerning the origin of the universe, as it does to talk of its being generated.

We know a cause (intelligence) adequate to the appearances, which we wish to account for: we have this cause continually producing similar appearances: yet, rejecting this cause, the sufficiency of which we know, and the action of which is constantly before our eyes, we are invited to resort to suppositions, destitute of a single fact for their support, and confirmed by analogy with which we are acquainted. Were it necessary to inquire into the

motives of men's opinions, I mean their motives separate from their arguments, I should almost suspect, that, because the proof of a Deity drawn from the constitution of nature is not only popular but vulgar, (which may arise from the cogency of the proof, and be indeed its highest recommendation,) and because it is a species almost of puerility to take up with it, for these reasons, minds, which are habitually in search of invention and originality, feel a resistless inclination to strike off into other solutions and other expositions. The truth is, that many minds are not so indisposed to any thing which can be offered to them, as they are to the *flatness* of being content with common reasons; and, what is most to be lamented, minds conscious of superiority are the most liable to this repugnancy.

The "suppositions" here alluded to, all agree in one character. They all endeavour to dispense with the necessity in nature of a particular, personal, intelligence; that is to say, with the exertion of an intending, contriving mind, in the structure and formation of the organized constitutions which the world contains. They would resolve all productions into *unconscious* energies, of a like kind, in that respect, with attraction, magnetism, electricity, &c. without any thing further.

In this the old systems of atheism and the new agree. And I much doubt, whether the new schemes have advanced any thing upon the old, or done more than changed the terms of the nomenclature. For instance, I could never see the difference between the antiquated system of atoms, and Buffon's organic molecules. This philosopher having made a planet by knocking off from the sun a piece of melted glass, in consequence of the stroke of a comet; and having set it in motion, by the same stroke, both round its own axis and the sun, finds his next difficulty to be, how to bring plants and animals upon it. In order to

solve this difficulty, we are to suppose the universe replenished with particles, endowed with life, but without organization or senses of their own; and endowed also with a tendency to marshal themselves into organized forms. The concourse of these particles, by virtue of this tendency, but without intelligence, will, or direction, (for I do not find that any of these qualities are ascribed to them,) has produced the living forms which we now see.

Very few of the conjectures, which philosophers hazard upon these subjects, have more of pretension in them, than the challenging you to show the direct impossibility of the hypothesis. In the present example, there seemed to be a positive objection to the whole scheme upon the very face of it; which was, that, if the case were as here represented, *new* combinations ought to be perpetually taking place; new plants and animals, or organized bodies which were neither, ought to be starting up before our eyes every day. For this, however, our philosopher has an answer. Whilst so many forms of plants and animals are already in existence, and, consequently, so many "internal molds," as he calls them, are prepared and at hand, the organic particles run into these molds, and are employed in supplying an accession of substance to them, as well for their growth, as for their propagation. By which means things keep their ancient course. But, says the same philosopher, should any general loss or destruction of the present constitution of organized bodies take place, the particles, for want of "molds" into which they might enter, would run into different combinations, and replenish the waste with new species of organized substances.

Is there any history to countenance this notion? Is it known, that any destruction has been so repaired? any desert thus re-peopled?

So far as I remember, the only natural appearance mentioned by our author, by way of fact whereon to build his hypothesis, the only support on which it rests, is the formation of *worms* in the intestines of animals, which is here ascribed to the coalition of superabundant organic particles, floating about in the first passages; and which have combined themselves into these simple animal forms, for want of internal molds, or of vacancies in those molds, into which they might be received. The thing referred to is rather a species of facts, than a single fact; as some other cases may, with equal reason, be included under it. But to make it a fact at all, or, in any sort, applicable to the question, we must begin with asserting an *equivocal* generation contrary to analogy, and without necessity: contrary to analogy, which accompanies us to the very limits of our knowledge or inquiries, for wherever, either in plants or animals, we are able to examine the subject, we find procreation from a parent form; without necessity, for I apprehend that it is seldom difficult to suggest methods, by which the eggs, or spawn, or yet invisible rudiments of these vermin, may have obtained a passage into the cavities in which they are found.* Add to this, that their *constancy to their species*, which, I believe, is as regular in these as in the other vermes, decides the question against our philosopher, if, in truth, any question remained upon the subject.

Lastly; these wonder-working instruments, these "internal molds," what are they after all? what, when examined, but a name without signification; unintelligi-

* I trust I may be excused, for not citing, as another fact which is to confirm the hypothesis, a grave assertion of this writer, that the branches of trees upon which the stag feeds, break out again in its horns. Such *facts* merit no discussion.

ble, if not self-contradictory; at the best, differing nothing from the "essential forms" of the Greek philosophy? One short sentence of Buffon's work exhibits his scheme as follows. "When this nutritious and prolific matter, which is diffused throughout all nature, passes through the *internal mold* of an animal or vegetable, and finds a proper matrix or receptacle, it gives rise to an animal or vegetable of the same species." Does any reader annex a meaning to the expression, "internal mold," in this sentence? Ought it then to be said, that, though we have little notion of an internal mold, we have not much more of a designing mind? The very contrary of this assertion is the truth. When we speak of an artificer or an architect, we talk of what is comprehensible to our understanding, and familiar to our experience. We use no other terms, than what refer us for their meaning to our consciousness and observation; what express the constant objects of both: whereas names, like that we have mentioned, refer us to nothing; excite no idea; convey a sound to the ear, but I think do no more.

Another system, which has lately been brought forward, and with much ingenuity, is that of *appetencies*. The principle, and the short account, of the theory, is this. Pieces of soft, ductile matter, being endued with propensities or appetencies for particular actions, would, by continual endeavours, carried on through a long series of generations, work themselves gradually into suitable forms; and, at length, acquire, though perhaps by obscure and almost imperceptible improvements, an organization fitted to the action which their respective propensities led them to exert. A piece of animated matter, for example, that was endued with a propensity to *fly*, though ever so shapeless, though no other we will suppose than a round ball to begin with, would, in the course of ages, if not in

a million of years, perhaps in a hundred millions of years, (for our theorists, have eternity to dispose of, are never sparing in time,) acquire *wings*. The same tendency to locomotion in an aquatic animal, or rather in an animated lump which might happen to be surrounded by water, would end in the production of *fins:* in a living substance confined to the solid earth, would put out *legs* and *feet;* or, if it took a different turn, would break the body into ringlets, and conclude by *crawling* upon the ground.

Although I have introduced the mention of this theory into this place, I am unwilling to give to it the name of an *atheistic* scheme, for two reasons; first, because, so far as I am able to understand it, the original propensities and the numberless varieties of them (so different, in this respect, from the laws of mechanical nature, which are few and simple) are, in the plan itself, attributed to the ordination and appointment of an intelligent and designing Creator: secondly, because, likewise, that large postulatum, which is all along assumed and presupposed, the faculty in living bodies of producing other bodies organized like themselves, seems to be referred to the same cause; at least is not attempted to be accounted for by any other. In one important respect, however, the theory before us coincides with atheistic systems, viz. in that, in the formation of plants and animals, in the structure and use of their parts, it does away final causes. Instead of the parts of a plant or animal, or the particular structure of the parts, having been intended for the action or use to which we see them applied, according to this theory they have themselves grown out of that action, sprung from that use. The theory therefore dispenses with that which we insist upon, the necessity, in each particular case, of an intelligent, designing mind, for the contriving and determining of the forms which organized bodies bear. Giv-

our philosopher these appetencies; give him a portion of living irritable matter (a nerve, or the clipping of a nerve,) to work upon; give also to his incipient or progressive forms, the power in every stage of their alteration, of propagating their like; and, if he is to be believed, he could replenish the world with all the vegetable and animal productions which we at present see in it.

The scheme under consideration is open to the same objection with other conjectures of a similar tendency, viz. a total defect of evidence. No changes, like those which the theory requires, have ever been observed. All the changes in Ovid's Metamorphoses might have been effected by these appetencies, if the theory were true; yet not an example, nor the pretence of an example, is offered, of a single change being known to have taken place. Nor is the order of generation obedient to the principle upon which this theory is built. The mammæ* of the male have not vanished by inusitation; *nec curtorum, per multa sæcula, Judæorum propagini deest præputium.* It is easy to say, and it has been said, that the alterative process is too slow to be perceived; that it has been carried on through tracts of immeasurable time; and that the present order of things is the result of a gradation, of which no human record can trace the steps. It is easy to say this; and yet it is still true that the hypothesis remains destitute of evidence.

The *analogies* which have been alledged are of the following kind. The *bunch* of a camel, is said to be no other than the effect of carrying burthens; a service in

* I confess myself totally at a loss to guess at the reason, either final or efficient, for this part of the animal frame, unless there be some foundation for an opinion, of which I draw the hint from a paper of Mr. Everard Home's, (Phil. Transac. 1799, p. 2.) viz. that the mammæ of the fœtus may be formed before the sex is determined.

which the species has been employed from the most ancient times of the world. The first race, by the daily loading of the back, would probably find a small grumous tumour to be formed in the flesh of that part. The next progeny would bring this tumour into the world with them. The life, to which they were destined, would increase it. The cause, which first generated the tubercle, being continued, it would go on, through every succession, to augment its size, till it attained the form and the bulk under which it now appears. This may serve for one instance; another, and that also of the passive sort, is taken from certain species of birds. Birds of the *crane* kind, as the crane itself, the heron, bittern, stork, have, in general, their thighs bare of feathers. This privation is accounted for from the habit of wading in water, and from the effect of that element to check the growth of feathers upon these parts: in consequence of which, the health and vegetation of the feathers declined through each generation of the animal: the tender down, exposed to cold and wetness, became weak, and thin, and rare, till the deterioration ended in the result which we see, of absolute nakedness. I will mention a third instance, because it is drawn from an active habit, as the two last were from passive habits; and that is the *pouch* of the pelican. The description, which naturalists give of this organ is as follows: "From the lower edges of the under chap, hangs a bag, reaching from the whole length of the bill to the neck, which is said to be capable of containing fifteen quarts of water. This bag the bird has a power of wrinkling up into the hollow of the under chap. When the bag is empty it is not seen: but when the bird has fished with success, it is incredible to what an extent it is often dilated. The first thing the pelican does in fishing, is to fill the bag; and

then it returns to digest its burthen at leisure. The bird preys upon the large fishes, and hides them by dozens in its pouch. When the bill is opened to its widest extent, a person may run his head into the bird's mouth; and conceal it in his monstrous pouch, thus adapted for very singular purposes."* Now this extraordinary conformation, is nothing more, say our philosophers, than the result of habit; not of the habit or effort of a single pelican, or of a single race of pelicans, but of a habit perpetuated through a long series of generations. The pelican soon found the conveniency, of reserving in its mouth, when its appetite was glutted, the remainder of its prey, which is fish. The fulness produced by this attempt, of course stretched the skin which lies between the under chaps, as being the most yielding part of the mouth. Every distension increased the cavity. The original bird, and many generations which succeeded him, might find difficulty enough in making the pouch answer this purpose: but future pelicans, entering upon life with a pouch derived from their progenitors, of considerable capacity, would more readily accellerate its advance to perfection, by frequently pressing down the sac with the weight of fish which it might now be made to contain.

These, or of this kind, are the analogies relied upon. Now in the first place, the instances themselves are unauthenticated by testimony; and in theory, to say the least of them, open to great objections. Who ever read of camels without bunches, or with bunches less than those with which they are at present usually formed? A bunch, not unlike the camel's, is found between the shoulders of the buffalo; of the origin of which it is impossible to give the account which is here given. In the second example; Why should the application of water, which appears to

* Goldsmith, vol. vi. p. 52.

promote and thicken the growth of feathers upon the bodies and breasts of geese and swans and other water fowls, have divested of this covering the thighs of cranes? The third instance, which appears to me as plausible as any that can be prodoced, has this against it, that it is a singularity restricted to the species; whereas, if it had its commencement in the cause and manner which have been assigned, the like conformation might be expected to take place in other birds, which feed upon fish. How comes it to pass, that the pelican alone was the inventress, and her descendants the only inheritors, of this curious resource?

But it is the less necessary to controvert the instances themselves, as it is a straining of analogy beyond all limits of reason and credibility, to assert that birds, and beasts, and fish, with all their variety and complexity of organization have been brought into their forms, and distinguished into their several kinds and natures, by the same process (even if that process could be demonstrated, or had ever been actually noticed) as might seem to serve for the gradual generation of a camel's bunch, or a pelican's pouch.

The solution, when applied to the works of nature *generally*, is contradicted by many of the phenomena, and totally inadequate to others. The *ligaments* or strictures, by which the tendons are tied down at the angles of the joints, could, by no possibility, be formed by the motion or exercise of the tendons themselves; by any appetency exciting these parts into action; or by any tendency arising therefrom. The tendency is all the other way: the conatus in constant opposition to them. Length of time does not help the case at all, but the reverse. The *valves* also in the blood-vessels, could never be formed in the manner, which our theorist proposes. The blood, in its

right and natural course, has no tendency to form them. When obstructed or refluent, it has the contrary. These parts could not grow out of their use, though they had eternity to grow in.

The *senses* of animals appear to me altogether incapable of receiving the explanation of their origin which this theory affords. Including under the word "sense" the organ and the perception, we have no acconnt of either. How will our philosopher get at *vision*, or make an eye? How should the blind animal effect sight, of which blind animals, we know, have neither conception nor desire? Affecting it, by what operation of its will, by what endeavour to see, could it so determine the fluids of its body, as to inchoate the formation of an eye? or, suppose the eye formed, would the perception follow? The same of the other senses. And this objection holds its force, ascribe what you will to the hand of time, to the power of habit, to changes, too slow to be observed by man, or brought within any comparison which he is able to make of past things with the present: concede what you please to these arbitrary and unattested suppositions, how will they help you? Here is no inception. No laws, no course, no powers of nature which prevail at present, nor any analogous to these, could give commencement to a new sense. And it is in vain to inquire, how that might proceed, which could never *begin*.

I think the senses, to be the most inconsistent with the hypothesis before us, of any part of the animal frame. But other parts are sufficiently so. The solution does not apply to the parts of animals, which have little in them of motion. If we could suppose joints and muscles to be gradually formed by action and exercise, what action or exercise could form a skull, or fill it with brains? No ef-

fort of the animal could determine the clothing of its skin. What conatus could give prickles to the porcupine or hedgehog, or to the sheep its fleece?

In the last place; what do these appetencies mean when applied to plants; I am not able to give a signification to the term, which can be transferred from animals to plants; or which is common to both. Yet a no less successful organization is found in plants, than what obtains in animals. A solution is wanted for one as well as the other.

Upon the whole; after all the struggles of a reluctant philosophy, the necessary resort is to a Deity. The marks of *design* are too strong to be got over. Design must have had a designer. That designer must have been a person. That person is God.

CHAPTER XXIV.

OF THE NATURAL ATTRIBUTES OF THE DEITY.

IT is an immense conclusion, that there is a God; a perceiving, intelligent, designing Being; at the head of creation, and from whose will it proceeded. The *attributes* of such a Being, suppose his reality to be proved, must be adequate to the magnitude, extent, and multiplicity of his operations: which are not only vast beyond comparison with those performed by any other power, but, so far as respects our conceptions of them, infinite, because they are unlimited on all sides.

Yet the contemplation of a nature so exalted, however surely we arrive at the proof of its existence, overwhelms our faculties. The mind feels its powers sink under the subject. One consequence of which is, that from painful abstraction the thoughts seek relief in sensible ima-

From whence may be deduced the ancient and almost universal, propensity to idolatrous substitutions. They are the resources of a labouring imagination. False religions usually fall in with the natural propensity: true religions, or such as have derived themselves from the true, resist it.

It is one of the advantages of the revelations which we acknowledge, that, whilst they reject idolatry with its many pernicious accompaniments, they introduce the Deity to human apprehension, under an idea more personal, more determinate, more within its compass, than the theology of nature can do. And this they do by representing him exclusively under the relation in which he stands to ourselves; and, for the most part, under some precise character, resulting from that relation, or from the history of his providences. Which method suits the span of our intellects much better, than the universality which enters into the idea of God, as deduced from the views of nature. When therefore, these representations are well founded in point of authority, (for all depends upon that,) they afford a condescension to the state of our faculties, of which, those, who have reflected most upon the subject, will be the first to acknowledge the want and the value.

Nevertheless, if we be careful to imitate the documents of our religion, by confining our explanations to what concerns ourselves, and do not affect more precision in our ideas than the subject allows of, the several terms, which are employed to denote the attributes of the Deity, may be made, even in natural religion, to bear a sense, consistent with truth and reason, and not surpassing our comprehension.

These terms are, omnipotence, omniscience, omnipresence, eternity, self-existence, necessary existence, spirituality.

"Omnipotence," "omniscience;" infinite power, infinite knowledge, are *superlatives;* expressing our conception of these attributes in the strongest, and most elevated terms, which language supplies. We ascribe power to the Deity under the name of "omnipotence," the strict and correct conclusion being, that a power, which could create such a world as this is, must be, beyond all comparison, greater than any which we experience in ourselves, than any which we observe in other visible agents; greater, also, than any which we can want, for our individual protection and preservation, in the Being upon whom we depend. It is a power likewise, to which we are not authorized by our observation or knowledge, to assign any limits of space or duration.

Very much of the same sort of remark is applicable to the term "omniscience," infinite knowledge, or infinite wisdom. In strictness of language, there is a difference between knowledge and wisdom; wisdom always supposing action, and action directed by it. With respect to the first, viz. knowledge, the Creator must *know*, intimately, the constitution and properties of the things which he created: which seems also to imply a foreknowledge of their action upon one another, and of their changes; at least, so far as the same result from trains of physical and necessary causes. His omniscience also, as far as respects things present, is deducible from his nature, as an intelligent being, joined with the extent, or rather the universality, of his operations. Where he acts, he is; and, where he is, he perceives. The *wisdom* of the Deity, as testified in the works of creation, surpasses all idea we have of wisdom, drawn from the highest intellectual operations of the highest class of intelligent Beings with whom we are acquainted; and, which is of the chief importance to us, whatever be its compass or extent, which it is evi

dently impossible that we should be able to determine, it must be adequate to the conduct of that order of things under which we live. And this is enough. It is of very inferior consequence, by what terms we express our notion, or rather our admiration of this attribute. The terms, which the piety and the usage of language have rendered habitual to us, may be as proper as any other. We can trace this attribute much beyond what is necessary for any conclusion to which we have occasion to apply it. The degree of knowledge and power, requisite for the formation of created nature, cannot, with respect to us, be distinguished from infinite.

The divine "omnipresence" stands, in natural theology, upon this foundation. In every part and place of the universe, with which we are acquainted, we perceive the exertion of a power, which we believe, mediately or immediately, to proceed from the Deity. For instance; in what part or point of space, that has ever been explored, do we not discover attraction? In what regions, do we not find light? In what accessible portion of our globe, do not we meet with gravity, magnetism, electricity; together with the properties also and powers of organized substances, of vegetable or of animated nature? Nay, further, we may ask, what kingdom is there of nature, what corner of space, in which there is any thing that can be examined by us, where we do not fall upon contrivance and design? The only reflection perhaps which arises in our minds from this view of the world around us is, that the laws of nature every where prevail; that they are uniform and universal. But what do we mean by the laws of nature, or by any law? Effects are produced by power, not by laws. A law cannot execute itself. A law refers us to an agent. Now an agency so general, as that we cannot discover its absence, or assign the place in which

some effect of its continued energy is not found, may, in popular language at least, and, perhaps, without much deviation from philosophical strictness, be called universal; and, with not quite the same, but with no inconsiderable propriety, the person or Being, in whom that power resides, or from whom it is derived, may be taken to be *omnipresent*. He who upholds all things by his power, may be said to be every where present.

This is called a virtual presence. There is also what metaphysicians denominate an essential ubiquity: and which idea the language of scripture seems to favour: but the former, I think, goes as far as natural theology carries us.

"Eternity," is a negative idea, clothed with a positive name. It supposes, in that to which it is applied, a present existence; and is the negation of a beginning, or an end of that existence. As applied to the Deity, it has no been controverted by those who acknowledge a Deity at all. Most assuredly, there never was a time in which nothing existed, because that condition must have continued. The universal blank must have remained; nothing could rise up out of it; nothing could ever have existed since; nothing could exist now. In strictness, however, we have no concern with duration prior to that of the visible world. Upon this article, therefore, of theology, it is sufficient to know, that the contriver necessarily existed before the contrivance.

"Self-existence," is another negative idea, viz. the negation of a preceding cause, as of a progenitor, a maker, an author, a creator.

"Necessary existence," means demonstrable existence.

"Spirituality" expresses an idea, made up of a nega-

tive part, and of a positive part. The negative part, consists in the exclusion of some of the known properties of matter, especially of solidity, of the vis inertiæ, and of gravitation. The positive part, complies perception, thought, will, power, action, by which last term is meant the origination of motion; the quality, perhaps, in which resides the essential superiority of spirit over matter, "which cannot move, unless it be moved; and cannot but move, when impelled by another.*" I apprehend that there can be no difficulty in applying to the Deity both parts of this idea.

*Bishop Wilkin's Principles of Nat. Rel. p. 106.

CHAPTER XXV.

THE UNITY OF THE DEITY.

OF the "unity of the Deity" the proof is, the *uniformity* of plan observable in the universe. The universe itself is a system; each part either depending upon other parts, or being connected with other parts by some common law of motion, or by the presence of some common substance. One principle of gravitation causes a stone to drop towards the earth, and the moon to wheel round it. One law of attraction carries all the different planets about the sun. This philosophers demonstrate. There are also other points of agreement amongst them, which may be considered as marks of the identity of their origin, and of their intelligent author. In all are found the convenience and stability derived from gravitation. They all experience vicissitudes of days and nights, and changes of season. They all, at least Jupiter, Mars, and Venus, have

the same advantages from their atmospheres as we have. In all the planets, the axes of rotation are permanent. Nothing is more probable, than that the same attracting influence, acting according to the same rule, reaches to the fixed stars: but if this be only probable, another thing is certain, viz. that the same element of light does. The light from a fixed star affects our eyes in the same manner, is refracted and reflected according to the same laws, as the light of a candle. The velocity of the light of the fixed stars, is also the same as the velocity of the light of the sun, reflected from the satellites of Jupiter. The heat of the sun, in kind, differs nothing from the heat of a coal fire.

In our globe the case is clearer. New countries are continually discovered, but the old laws of nature are always found in them: new plants, perhaps, or animals, but always in company with plants and animals, which we already know; and always possessing many of the same general properties. We never get amongst such original, or totally different, modes of existence, as to indicate, that we are come into the province of a different Creator, or under the direction of a different will. In truth, the same order of things attends us, wherever we go. The elements act upon one another, electricity operates, the tides rise and fall, the magnetic needle elects its position, in one region of the earth and sea, as well as in another. One atmosphere invests all parts of the globe, and connects all; one sun illuminates; one moon exerts its specific attraction upon all parts. If there be a variety in natural effects, as, e. g. in the tides of different seas, that very variety is the result of the same cause, acting under different circumstances. In many cases this is proved; in all is probable.

The inspection and comparison of *living* forms

this argument examples without number. Of all large terrestrial animals the structure is very much alike. Their senses nearly the same. Their natural functions and passions nearly the same. Their viscera nearly the same, both in substance, shape, and office. Digestion, nutrition, circulation, secretion, go on, in a similar manner, in all. The great circulating fluid is the same: for, I think, no difference has been discovered in the properties of *blood*, from whatever animal it be drawn. The experiment of transfusion proves, that the blood of one animal will serve for another. The *skeletons* also of the larger terrestrial animals, show particular varieties, but still under a great general affinity. The resemblance is somewhat less, yet sufficiently evident, between quadrupeds and birds. They are alike in five respects, for one in which they differ.

In *fish*, which belong to another department, as it were, of nature, the points of comparison become fewer. But we never lose sight of our analogy, e. g. we still meet with a stomach, a liver, a spine; with bile and blood; with teeth; with eyes, which eyes are only slightly varied from our own, and which variation, in truth, demonstrates, not an interruption, but a continuance, of the same exquisite plan; for it is the adaptation of the organ to the element, viz. to the different refraction of light passing into the eye out of a denser medium. The provinces, also, themselves, of water and earth, are connected by a species of animals which inhabit both; and also by a large tribe of aquatic animals, which closely resemble the terrestrial in their internal structure: I mean the cetacious tribe, which have hot blood, respiring lungs, bowels, and other essential parts, like those of land animals. This similitude, surely, bespeaks the same creation and the same Creator.

Insects and *shell-fish* appear to me to differ from other